PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

VOL. CXIV.—No. 2959.] *LONDON: FRIDAY, SEPTEMBER 15, 1922.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

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SESSION 1922-23.

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T. A. COGHLAN,
Agent-General for New South Wales.
Australia House,
London, W.C. 2.
14th July, 1922. U 197

METROPOLITAN BOROUGH OF WOOLWICH.

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The Tenders must be on Forms supplied, and in strict accordance with the conditions stated.
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By Order,
ARTHUR B. BRYCESON,
Town Clerk.
W 235

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W 286

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The Waterworks Committee invite

Tenders for the Laying and

JOINTING of about 28 MILES of CAST-IRON PIPES, 35 in. dia., five miles 19 in. dia., and short lengths of other diameters, and the CONSTRUCTION of a SERVICE RESERVOIR, BRIDGES, VALVE HOUSES, and other works incidental to the piping, all of which will be situated in the valley of the River Usk. Plans and Drawings may be seen and Specification obtained at the offices of the Engineers, G. H. HILL & SONS (Westminster), 3, Victoria Street, Westminster, on payment of Five Pounds, which will be returned to the tenderer provided that he shall have sent in a *bona fide* Tender and shall not have withdrawn the same and shall have returned the documents and drawings lent to him. The said sum will also be returned to any applicant who decides not to tender, if the documents and drawings are returned within seven days of their issue to him. A limited number of sets of the Drawings, uncoloured, excluding Ordnance maps, are available for lending to persons who have applied for the Specification, and will be lent to such persons in priority of application on payment of the sum of Three Pounds, which sum will not be returned. Inspection of site, Wednesday, the 27th September. Sealed Tenders, endorsed "Talybont Scheme. Tender for Contract No. 4," and addressed to the undersigned, must be received by me not later than Saturday, the 21st October. The Committee do not bind themselves to accept the lowest or any Tender. The Contractor will be required to pay Trades Union rates of wages, and observe the recognised hours and rules of labour.

O. T. MORGAN,
Town Clerk.
Town Hall, Newport (Mon.),
14th September, 1922. W 313

ABERDEEN CORPORATION WATERWORKS.

EXTENSIONS 1920.

CONTRACT No. 7—NEW AQUEDUCT.

The Town Council of Aberdeen are prepared to receive

Tenders from Competent

Persons willing to enter into a Contract for the TRANSPORTING, LAYING and JOINTING of TWO MILES of 48 in. MILD STEEL PIPING and Ancillary Works, between Gateside of Inchmarlo and Banchory Railway Station.
The Drawings may be inspected, and Specifications, Schedule of Quantities, and Forms of Tender obtained, on and after 21st September, 1922, on application at the Water Engineer's Office, 41½, Union Street, Aberdeen.
For each Specification a deposit of Five Pounds Sterling in cash will be required, which sum will, after a Tender has been accepted, be returned to the Tenderer, provided that he shall have sent in a *bona fide* Tender, based on the Drawings, Specification, and Schedule of Quantities provided, with the Schedule of Quantities fully priced out in detail, and shall not have withdrawn the same.
Tenders on the Forms prescribed and enclosed in securely sealed envelopes endorsed "Tender for New Aqueduct," and addressed to the undersigned, must be delivered not later than 11th October, 1922.
The Town Council do not bind themselves to accept the lowest or any Tender.

GEORGE MITCHELL, M.Inst.C.E.,
Water Engineer.
Water Engineer's Office,
41½, Union Street, Aberdeen.
12th September, 1922. W 293

BARCELONA INTERNATIONAL EXHIBITION OF ELECTRICAL AND GENERAL SPANISH INDUSTRIES.

In fulfilment of the resolution of the Administrative Court and for a period beginning with the publication of this advertisement to the 30th of the month of November, at Seven o'clock p.m., an INTERNATIONAL COMPETITION will be opened for

Tenders for the Construction

of the GRAND PALACH OF NATIONS.
At the offices of the Exhibition (Lerida Street) during the usual hours on every working day (from 9.30 to 1 and from 6.10 to 9.10) there will be on view the Specification of Conditions and the plans of the said building, and further, for all those desiring to take part in the competition, subject to payment beforehand, there will be handed a copy of the said Specification of Conditions applying to same and a set of the said plans.
On Tuesday each week from 6.10 until 8.10 o'clock, and if this day is not available, on the following one, the architect who designed the plans, DON JOSÉ PUIG Y CADAFALCH will be at the offices of the exhibition for the purpose of giving competitors who desire it, any explanations they may think suitable for the better knowledge of the work to be executed and the amount of which they have to estimate for.
The presentation of Tenders and other things necessary to observe will be effected in the form laid down in the last Heading in the Specification.
Barcelona, 13th September, 1922.

F. SANS Y BUIGAS,
Legal Official. W 291

LITERATURE.

Manufacture of Portland Cement. By ARTHUR C. DAVIS, M.Inst.C.E.I., F.C.S. Third edition, revised and enlarged. Dublin: John Falconer, 1922. [Price 25*s.*]

THIS is the third edition of a work describing the manufacture and testing of Portland cement, an industry essentially British in its origin, and whose subsequent progressive development owes much to British enterprise. The details of manufacture being fairly simple and the operations few, less attention has been given to the underlying theory than its importance deserves or the interests of the industry and of engineering demand. To preserve the pre-eminence already won, it is necessary in face of severe competition from America and the Continent, to avail ourselves of both the experience of the past and of the further assistance scientific research can afford. This work considers both successful achievement and future endeavour, and in the hope that manufacturers and consumers will both adopt more scientific measures, confidently anticipates a wider prosperity in an industry that is daily increasing in importance. It is gratifying to know that two editions have already been absorbed. The preface of this third edition has been supplied by the publisher, and asserts that the edition has been entirely re-written and new matter inserted to bring the information up to date, but by whose hand the revision has been made is not clear. References to recent research might have been fuller, particularly in relation to work accomplished by the Bureau of Standards and to views held concerning the causes that operate to increase the strength of hydrated plaster. It is not improbable, but that the processes of solidification in metals may be repeated in cement, and that the presence of amorphous material may be as potent a factor as the interlocking radiating needles of adjacent spherulites, on which attention has hitherto been fixed. In a handbook, the statement of accepted facts is perhaps more desirable than the discussion of hypotheses, which may fail on further inquiry, but the indications of lines of further research are always stimulating.

The contents are very well arranged. An introductory chapter sketches the history of the subject from the time when lime, silica and alumina were first combined to furnish a hydraulic cement as a commercial article, and indicates the character of the operations to which they are submitted. It is less than a hundred years since the construction of the Thames Tunnel created a demand for this mixture of calcareous and argillaceous material. Now the capital invested in the factories of this country alone amounts to some 14,000,000*l.*, while the industry gives employment to more than 12,000 operatives. This rapid expansion is due in a great measure to the wide distribution of suitable raw materials, since any constituent of the Earth's crust capable of yielding by calcination the silicates and aluminates of lime may be used for its manufacture. But though the materials are plentiful the proportions in which they are mixed is a matter of prime importance, demanding from expert chemists continual watchfulness in selecting and grading the raw materials as they are delivered from the quarry. For if the materials are not mixed within very narrow limits of error, nothing can be done to remedy the initial fault, and an inferior cement is the result. The author therefore discusses the principles that determine selection with great care and fullness, but makes no mention of the possibilities of finely-ground blast-furnace slag as a desirable addition to the chalk and clay, which furnish the bulk of the raw materials. Generally it may be inferred that he is opposed to the use of ground slag, on account of possible sulphur contamination, but the evidence of improvement from its use is increasing, and the prospect of utilising such a cumbersome waste product is inviting. A small percentage of oxide of iron as a flux is recommended, as it causes the silica and alumina to combine with the lime at a lower temperature than otherwise would be possible, but this does not touch the slag problem. The iron combination is not hydraulic and has no concreting power.

Having obtained the requisite proportions of the ingredients, intimate mixing must be effected, necessitating fine crushing of the materials, and a dry or wet process will be employed according to the hardness of the several constituents handled. A finely-divided condition is necessary as a preliminary to the processes of burning or calcining the raw product to the point of vitrification, in order to produce the so-called cement clinker, in which the silica and alumina of the clay enter into combination with the lime. Finally the clinker is very finely ground and is ready for marketing.

The interest and the value of the book centre in the description of details. The processes in general use, modified as they have been by time and knowledge, are very well described, the distinguishing features of the several types of kilns, whether intermittent or of continuous action, in which the materials are raised to a temperature of about 1,400 deg. C., being carefully reviewed. The rotary kiln, however, by reason of its advantages over competitors and the revolution it has worked in the industry, demands particular attention, and justice is done to its efficiency and economical working. It is maintained that the product from the rotary kiln exhibits high tensile strength with age, and will also produce a cement absolutely free from all expansion and contraction tendencies. This happy result is brought about by a complete control over the temperature during the process of calcination. The rotating speed of the cylinder, the feed of the raw material, the force of the coal blast, and the quantity of fuel supplied are all regulated by the operator, making the process more certain and uniform, if demanding greater skill. The drying and grinding of the coal to an impalpable powder is of the utmost importance. The object is to reduce the coal to such a degree of fineness that when blown in at one end of the kiln the mixture of air and coal should burn as nearly as possible as a mixture of air and gas, the waste products being carried off. No mention is made of oil fuel, but it would seem that "atomised" oil should give good results.

The grinding of the clinker presents many opportunities for the exercise of ingenuity, in the choice between crushing and grinding. The mechanism of ball mills and tube mills is well described, though the illustrations are rather poor. The operations of grinding and crushing are demonstrated, and the explanation of the manner in which the flints roll on the contents of the drum differs materially from that given when the machinery was originally devised. The higher position of the feed opening as compared with that of the discharge is now seen to be of no importance in conveying the material. The finished cement is usually ground sufficiently fine to pass through a 180×180 mesh sieve, and though finer grinding is sometimes demanded, the author maintains that ultra fine grinding of cement has few real or permanent advantages. This raises the whole question of the value of physical testing and the confidence to be placed in certificates of test, as a guide to the qualities of strength and soundness. The author devotes very considerable space to the testing problem, and is clearly of opinion that owing to the uncertainty of the factors that enter, the only reliable guide is experience. He remarks with some pungency "that the precision and accuracy in any one of the physical tests vary almost exactly inversely to the importance of the test."

Coal. By ELWOOD S. MOORE, M.A., Ph.D. New York: John Wiley and Sons; London: Chapman and Hall, Limited. [Price 25*s.* net.]

No study is perhaps so pleasurable to those interested in the industrial developments of the world as that of the origin and history of our national sources of energy. The coal we use was produced by a series of gradual changes from the wood of ancient forests, either on the sites of growth or at places to which rivers had carried and deposited it. The character of the changes wood undergoes in its transformation to coal is exceedingly involved, and many questions relating to the processes have either remained untackled or have proved of considerable difficulty of solution. Work of this character has been conducted in all types of laboratories—geological, mining, chemical and physical—in all parts of the world, and the results of this work it is difficult to obtain in a ready, handy and comprehensive form. To those who are not devoting their whole workaday lives to specialisation in fuel studies there are many barriers to the acquisition of anything like a complete and clear understanding of these matters. A complete treatise on "Coal," by Elwood S. Moore, does much to provide authoritative, comprehensive and readable accounts of the origin, processes of formation, methods of location, mining and testing of this fuel. The author is Professor of Geology and Mineralogy, and Dean of the School of Mines of the Pennsylvania State College, and his work must not be regarded as merely another book on this subject, for although mostly devoted to American activity in this field, it is scholarly and thorough, and references are given to all the research work and original papers on which the various arguments are based. The origin of coal is discussed from the evidence available in the coal itself in the form of fossil remains and also from its association with mineral and rock deposits in its neighbourhood.

A problem difficult enough to be attractive to the most enthusiastic research worker is how the cellulose and lignocellulose of wood became more or less pure carbon in the course of time. Professor Moore discusses the theories and reviews the evidence for the different deductions regarding this transformation. Fallen trees, the spores, leaves and other plant *debris* continually drop into the waters and swamps and build up a layer of peat of considerable thickness, and from this accumulation in course of time the coal seam is produced. Photographs of drifting vegetation in rivers and its accumulation in delta deposits serve in giving a clear understanding of these actions. The illustrations of plant fossils in coal and their identification provides very interesting reading. The complexity of variation in coals provides difficulties of exact classification, whether by the relationship of the fixed carbon to the volatile combustible matter, the moisture content or the difference of the carbon, oxygen and ash, and the various proposed systems are reviewed and discussed.

Readers who are power engineers will find a great deal to interest them in this book in the chapters relating to the preparation and use of coal. The character of coal for producer gas installations, illuminating and water-gas production, for steam boilers and coking purposes are all considered, both in regard to physical properties and chemical composition. An interesting chart showing the distillation products of coal and their commercial uses with the accompanying treatment of the subject gives a clear impression of the magnitude and diverse character of the operations, quite apart from heat production, that are dependent on coal as their raw material. The work is well written, amply provided with production figures, geological and chemical treatment, and is a book that everyone interested in this fuel either from the standpoint of geologist, the mining engineer, the by-products chemist or power user will find most useful in dealing with his everyday work.

THE CANADIAN PACIFIC LINER "EMPRESS OF CANADA."

(*Continued from page* 258.)

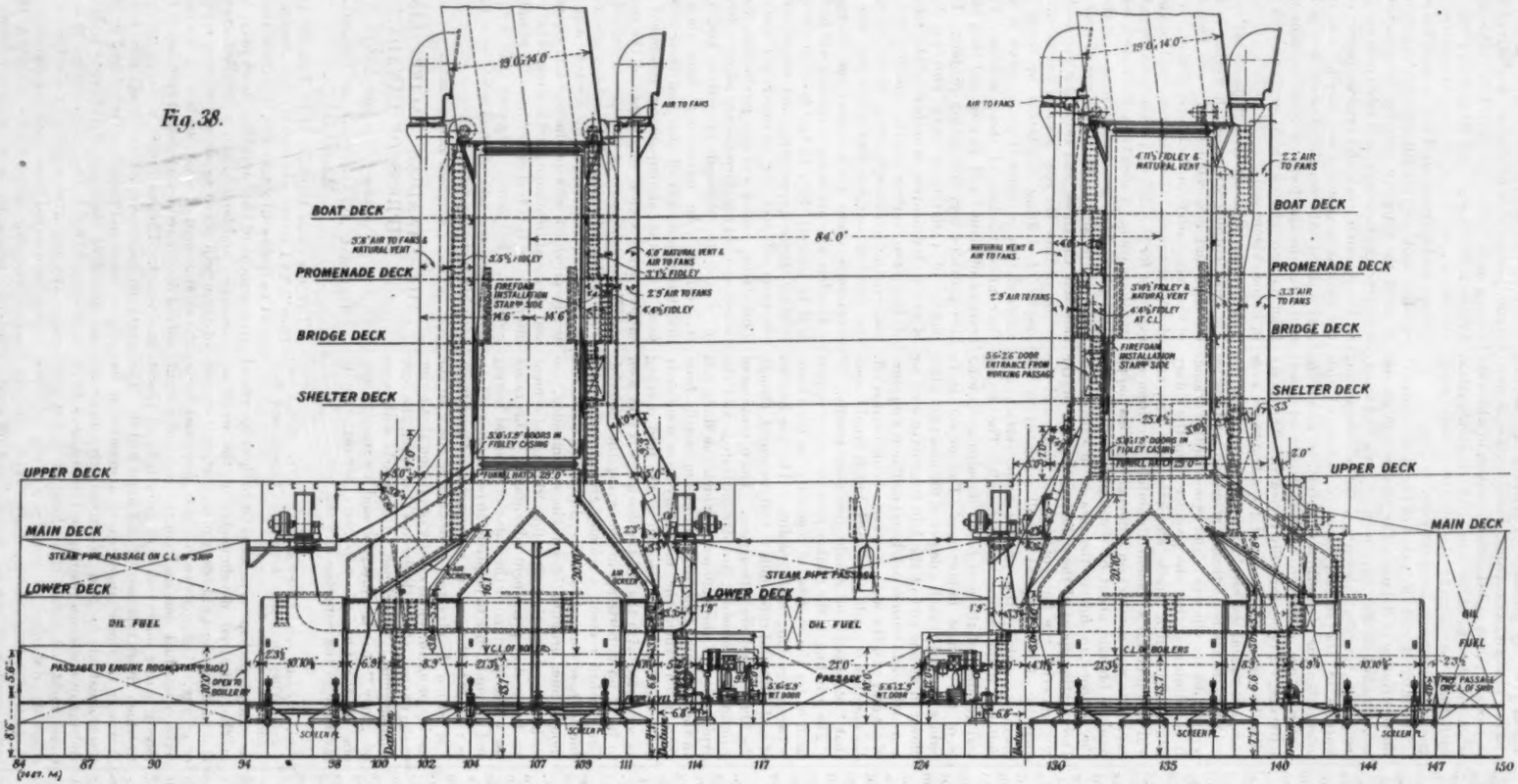
GENERAL ARRANGEMENT OF PROPELLING MACHINERY.

THE drawings reproduced in Figs. 30 to 37 on Plate XXVI accompanying this issue, and in Figs. 38 to 41 on pages 318 and 319, illustrate the general arrangement of the propelling machinery, auxiliary machinery and boilers, and a detailed examination of them will serve to show the care expended in the arrangement of what, we believe, are the largest sets of double-reduction geared turbines so far fitted in a vessel. The machinery is placed in four watertight compartments, viz., two boiler rooms, the engine room and tunnel. The oil-fuel installations are placed at the ends of the watertight passage connecting the boiler rooms (see Figs. 38 and 39 on pages 318 and 319) while at the after end of the engine room on the lower deck, a flat stretching right across the ship gives ample space for the main electric generators and engineers' store rooms. This feature is best shown in Figs. 31 and 37 on Plate XXVI. Aft of the engine room, between the two lines of shafting, are situated the refrigerating plant and the engineers' workshop. As mentioned

THE CANADIAN PACIFIC LINER "EMPRESS OF CANADA": BOILER ROOMS.

CONSTRUCTED BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, ENGINEERS AND SHIPBUILDERS, GOVAN, GLASGOW.

Fig. 38.



in our previous article, a dummy funnel is fitted over the engine-room hatch, and this, acting as a large upcast shaft, ensures excellent ventilation to the engine room.

The propelling machinery is designed for a maximum total shaft horse power of about 24,500 at 112 r.p.m. of the propeller shaft, steam being supplied at 210 lb. per square inch, without superheat. We shall deal with the turbines in detail in a later article, but may now mention that there are altogether eight separate turbines in the engine room, each set of four working in series and driving two first-reduction pinions, as will be understood from the plan, Fig. 33 on Plate XXVI. The second reduction pinions are mounted on the same spindle as the first reduction wheel, and these drive the main gear wheel, which is 11 ft. 8 in. in diameter and weighs about 65 tons. The complete sets of gearing, with the casings and lifting tackle, each weigh approximately 200 tons, but they were lifted on board in complete units by means of the hammer-head crane at the Fairfield Yard, notwithstanding the large radius through which they had to be swung. The whole of the machinery has been constructed in accordance with Lloyd's and the Board of Trade requirements.

The Boiler Installation.

Steam is supplied by eight double-ended and four single-ended cylindrical return-tube boilers, burning either coal or oil fuel. They are arranged symmetrically in two boiler rooms as shown in Figs. 38 to 41 on the present page and page 319, and work under forced draught on the Howden system. Sufficient space has been provided in the stokeholds to enable coal to be fired efficiently, so that the floor space is particularly ample when oil, which is the normal fuel, is being employed. The uptakes from each boiler room are led to a separate funnel as is best shown in Fig. 38. The funnels, we may mention, are of oval section, the outer shell measuring 19 ft. by 14 ft. in each case, while the height of the upper end above the keel is 130 ft.

The boilers are each of 14 ft. 9 in. mean diameter, the double-ended being 22 ft. long and the single-ended 11 ft. 6 in. long. Three Morison furnaces, 42½ in. internal diameter, are fitted in each boiler end, so that there are 60 furnaces in all; the furnaces are arranged so that they can readily be converted for coal firing when necessary. When arranged for oil fuel, the total heating surface is about 53,000 sq. ft., and the total grate area, when fitted for burning coal, is 1,250 sq. ft. Air is supplied to the furnaces through the usual Howden tubular air heaters placed in the uptakes at the boiler fronts by eight electrically-driven fans installed in separate fan rooms on the main deck as shown in Figs. 38 and 40. The fan motors, it should be mentioned, can be controlled from the stokehold as well as from the fan room. The air is drawn to the fans through trunks from the forward and aft sides of the funnels at the fiddley tops, the arrangement of the trunking being clearly shown in Fig. 38. Each fan is capable of supplying 26,000 cub. ft. of air per minute when running at 500 r.p.m.; the diameter of the fan wheel is 72 in.

The Wallsend-Howden oil-fuel system is employed with Dahl burners, and, for supplying the burners, duplicate pressure-pumps with oil heaters and strainers, are installed in a recess in each boiler room, as shown in the elevation and plan given in Figs. 38 and 39 already referred to. Auxiliary heaters and pumps are also provided for lighting-up purposes. The space between the boiler rooms is divided into four oil bunker tanks, of which the two inner (see Fig. 39) are used for settling purposes; each tank has a capacity of about 350 tons. For transferring oil from the bunker tanks to the settling tanks, two 50 ton Weir pumps are fitted. Oil is also carried in bunker tanks forward and aft of the boiler rooms,

THE CANADIAN PACIFIC LINER "EMPRESS OF CANADA": BOILER ROOMS.

CONSTRUCTED BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, ENGINEERS AND SHIPBUILDERS, GOVAN, GLASGOW.

Fig. 39.

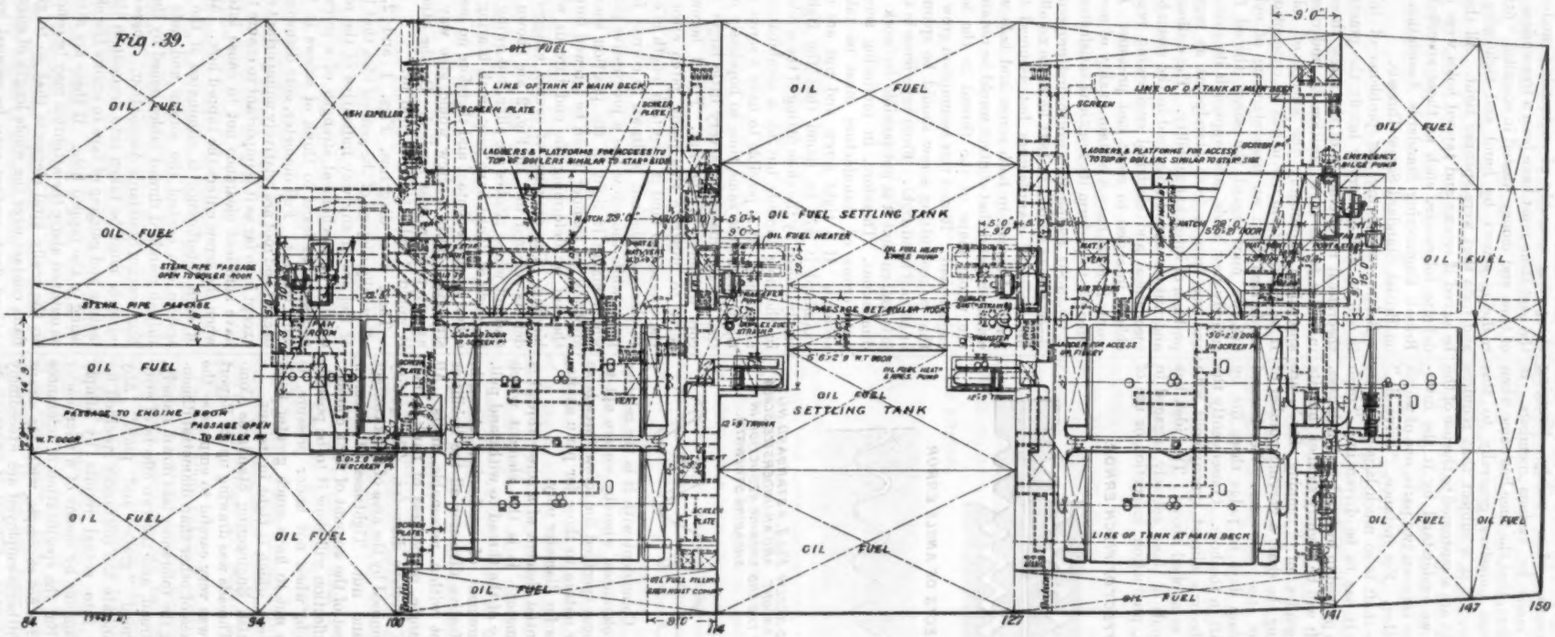


Fig. 40. SECTION AT FRAME 140. LOOKING FOR'D

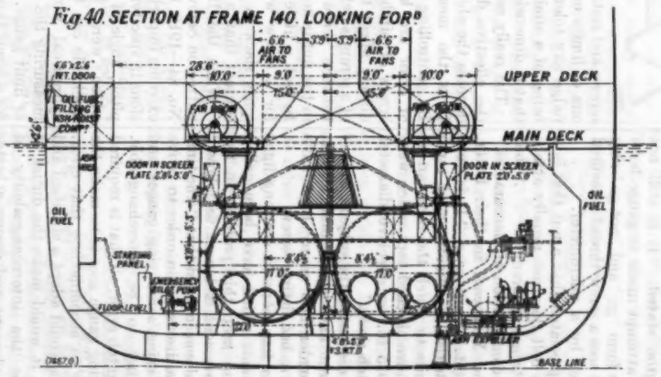
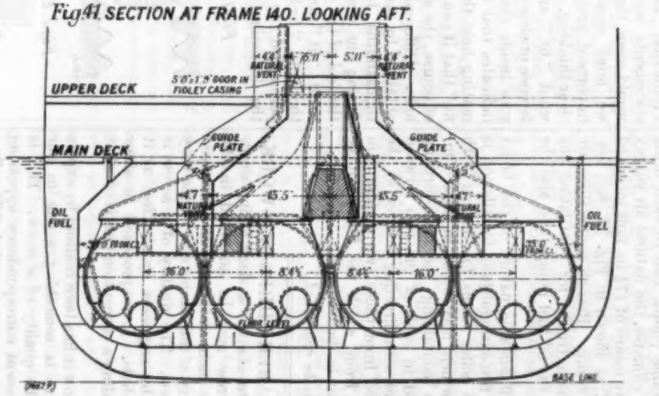


Fig. 41. SECTION AT FRAME 140. LOOKING AFT.



as shown in the plan Fig. 39, and also in the double bottom tanks, as mentioned in our previous article. For transferring the oil from the double-bottom tanks to the bunker tanks or settling tanks, two motor-driven Rotoplunge pumps are carried, each being capable of transferring 50 tons per hour.

In the view of the single stokehold of the forward boiler room reproduced in Fig. 42 on page 332, one of the Weir oil-fuel transfer pumps can be seen on the extreme left, while in the distance, near the centre, one of the observation tanks for dealing with the drains from the oil-fuel heating system will be noticed. It may also be of interest to mention that the photograph from which this engraving was prepared was taken immediately after the completion of a long trial run at sea. The cleanly and orderly state of the stokehold may thus be very favourably contrasted with the usual condition of the stokehold of a coal-fired vessel at the termination of a similar run.

The only other auxiliary in the boiler room is a Drysdale motor-driven emergency bilge pump having a capacity of 100 tons per hour and shown in Figs. 39 and 40 on this page, but it may be mentioned that Tracy purifiers have been fitted to all the boilers to prevent priming and to ensure that the steam supplied to the turbines shall be as dry as possible. To assist the engineer in keeping down

fuel consumption, CO_2 recorders of the "W.R." type are fitted in each boiler room. Particular attention has been paid to the ventilation of the stokeholds for which purpose four natural vent trunks, shown in Figs. 38 and 41, are led from the fiddley tops to suitable points, two to each firing space. In tropical climates, the natural air supply can be augmented by means of 17½ in. fans mounted on the casing tops, as shown in Fig. 38, and discharging into each trunk. Branch connections are provided on the main trunks for ventilating the recesses containing the oil-fuel pumps, and also the pipe passage.

In view of the inflammable nature of the boiler fuel a "Firefoam" fire-extinguishing installation is fitted in each of the boiler rooms for dealing with outbreaks of fire which may occur in these compartments. Tanks containing the foam-forming chemicals are fitted in each of the two forward funnel hatches, hoses with directing nozzles at the lower ends being led from these two positions, in the boiler rooms, from which the foam can be directed to any point in these rooms.

(To be continued.)

INTERCHANGEABLE THREADED WORK.

THE question as to whether a slack-fitting screw can be a good screw may be answered in the affirmative, though such an answer is challenged by the great majority of mechanics every time they make or use a screw. The quality of a screw is commonly judged by engineers by the feel as it enters its tapped hole. It is proposed to show how entirely misleading a conception this is of what is required.

For a long time now it has been realised by expert engineers that there is something wrong in our understanding of the quality of a screw. This is evidenced by the recent correspondence appearing in the pages of ENGINEERING entitled "The Production of Accurate Screw Threads." The letters referred to appeared over the names of the technical engineers of some of the leading firms in the country whose products are recognised as embodying the highest skill and scientific knowledge. The views expressed in these letters are well worthy of the earnest attention of all concerned with the manufacture and use of screws, studs and taps. We may quote from these letters as follows:—

Mr. A. A. Remington stated, "It is still not uncommon to see an attempt made to gauge bolts by means of complete form 'go' and 'not go' ring gauges. . . . One sees a screw thread measured over the top diameter by a micrometer. . . . It is not generally appreciated that a nut that is a nice spanner fit on a bolt does not usually attain that condition by extreme accuracy . . . but more frequently by a combination of inaccuracies."

Messrs. Armour and Muirhead, in their letter, bring out another point. They say: "It is very difficult to get the British manufacturer (of taps) to supply definite limits to which the taps can be made. . . . We have checked taps which were as much as plus 0·015 in. on effective diameter with a progressive pitch error."

Mr. G. R. Willis, in discussing the subject, wrote: "Every nut is suspect and needs some locking device . . . I wonder how many lives have been lost owing to a bad-fitting screw. . . . The projection system has focussed a strong light on the deplorable shams which have been called screws, and if we can keep this problem in the limelight some improvement is bound to follow."

Finally, Mr. J. Jamieson insisted that "The time is now ripe for such a discussion in order to prove the utter fallacy of using screw ring gauges and expecting the product to be interchangeable. . . . If there is a pitch error, all that is required to satisfy the screw ring gauge user is to make the threads thin in order to accommodate that error. . . . If tap makers would adopt a standard and guarantee their taps, it would make the duties of those responsible for the interchangeability of threaded work more pleasant and ensure a better product."

These are trenchant phrases and deserve careful consideration. Although the screw thread is one of the most widely-used mechanical devices, and one of the oldest, there is evidently a widespread misconception of its requirements in the way of measurement to ensure that it will fulfil its duties and still be interchangeable. This statement is emphasised by the discussion which took place recently on Mr. Fairbrother's paper before the Institution of Production Engineers, when widely diverging statements were made by various members. It would seem, therefore, that the time has come when we must re-address ourselves generally to this important problem. It is a subject that requires clear thinking. We are accustomed to the use of the word "fit" and we understand by it the interference or clearance between two parts, one of which goes inside the other. For instance, "drive fit" indicates that the shaft is so much larger than its mating hole that it has to be driven in; "push fit" that it can be pushed in by hand, in which case, of course, the shaft will be slightly smaller than its hole. Different grades of "running fits" are obtained by making the shaft a varying number of thousandths below the hole size. We learned during our workshop days to judge these fits by the feel of the shaft in the hole. Consequently the word "fit" has become almost synonymous with the word "feel" as applied above. This idea has permeated the minds of those actively engaged in the denomination, production, inspection or use of

Fig. 1. EFFECT OF PITCH ERROR.

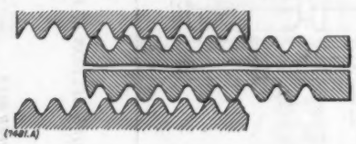


Fig. 2. EFFECTS OF ANGLE ERROR.

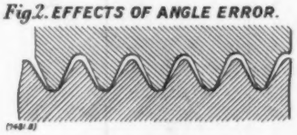


Fig. 3. A STANDARD SCREW AND NUT SHOWING AMOUNT OF METAL TO TAKE THE END PRESSURE.

Fig. 4. A STANDARD NUT AND AN UNDERSIZE SCREW SHEWING REDUCTION IN SHEARING STRENGTH.

screws and nuts. Coincident with it is the relative one of limits or tolerances, whereby we are apt to judge any tolerances specified for screw threads as being of a similar nature to those for plain shafts, that is dimensions for diameter only.

The really essential element of a screw thread is the effective diameter; it is this element which denotes the ability of the thread to withstand pull. It is the measurement of mechanical strength. By controlling effective diameter all the liabilities of error are kept within reasonable limits. All errors of pitch, angle, or flatness of flank immediately affect the effective diameter. The quality of a screw is determined by the area of flank contact between screw and nut. Tightness of a screw in the nut is no test of the amount of flank contact. In fact, a little reflection will show it to be possible for a screw which, when not under pressure, is quite slack in its nut to have much greater flank contact than a screw which is tight in its nut.

When the British Engineering Standards Committee on Screw Threads was drawing up its Report No. 84—1918, it was very careful to emphasise the extreme importance of other than diametral dimensions in specifying the tolerances laid down, namely, pitch, angle of thread, and the two effects of error which were termed "grade and play." Any mechanic can translate the tolerances specified for cylindrical work into actual results by simply measuring the diameter by means of a micrometer or limit gauge. But the specification of tolerances for a screw thread is not so simple, while the means of measurement hitherto employed are exceedingly complicated and far beyond the reach of the workman. This is probably one of the reasons why specified tolerances for screw threads have not been brought into more general use. With some simple means of inspecting screws it would become an easy matter to ensure that all screws used satisfied the two main requirements, mechanical strength and interchangeability.

This would also form an important element in cheapening assembly of engineering products. In the past there must have been a tremendous amount of time and money wasted in so-called "fitting"—re-dieing screws by hand and tightening screws and nuts that were spanner tight. All this would be saved if screws and tapped holes were made to definite tolerances, such as those specified in the British Engineering Standards Association reports on British Standard Screw Threads.

Before considering the problems of tolerances it will be well to survey briefly the practical and theoretical requirements of the screw thread itself in order to be in a position to understand and appreciate thoroughly the effects of tolerances. If we remove from our minds all conceptions of fit as derived from an understanding of cylindrical fits, we may regard the screw thread from an entirely new angle, and approach its manufacture and use from a fresh standpoint as regards the problem of interchangeability. The ordinary screw and nut or tapped hole used in the assembly of all mechanical and electrical engineering products is chiefly intended to resist end pressure. In other words it must have a certain quality of mechanical strength to perform its functions satisfactorily.

When Sir Joseph Whitworth first propounded his screw-thread system in 1841 he made no allowances for errors of manufacture but assumed that the forms of thread in both screw and hole would be coincident and that contact would be obtained over the whole shape of the thread in the length of engagement. Round this assumption grew the idea that a good-fitting screw should be spanner-tight or at least hand-tight. From experience in the shops it is known that it is not possible to work to dead dimensions. Therefore, in producing screws and nuts errors of manufacture must be taken into account. If a tight screw and nut are carefully examined it will be found that the tightness is rarely caused by the close fitting of the screw threads in the hole threads but by a combination of inaccuracies. It is possible to have a screw spanner-tight and at the same time so hopelessly undersize that its full diameter is very little larger than the core diameter of the nut. Fig. 1 herewith will serve to illustrate this point, pitch error causing the threads to bind if a certain length is exceeded. In this case the nut is drawn to correct form and pitch, while the screw has a progressive pitch error which makes it tight in the position shown. By applying the spanner it can be screwed further into the nut by deforming the end threads which are binding. The drawing, of course, exaggerates the defects referred to. In Fig. 2 are shown a screw and nut whose pitches are alike, but owing to errors in angle of flanks have very small bearing on each other, no flank contact and therefore no mechanical strength. Such a screw would give way as soon as any pressure was applied. On the other hand, it would "feel" to be a good fit.

These two diagrams, Figs. 1 and 2, should effectually dispose of the general idea that tightness or feel are in any way indicative of the real fit or quality or mechanical strength of a screw. It is necessary to learn to think of screws in terms of flank contact. Full diameter, core diameter, radius of crest and root are relatively unimportant elements, except in so far as it is important to ensure that they have sufficient clearance not to cause interference when the screw enters the tapped hole. All chance of such interference is eliminated if the gauging system can control the screws and nuts to the British standard thread tables issued by the British Engineering Standards Association. These elements however must be taken into account in the manufacture and gauging of taps to ensure the clearances being in the tapped hole. If these are attended to as outlined above the attention may be concentrated on the really vital elements that go to give good flank contact over the whole length of engagement.

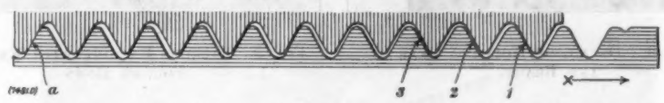
Good flank contact may be secured by a combination of: (1) Pitch of thread—the most variable element and the one most difficult to control; (2) angles of flanks—a feature which most tool

makers can control within fine limits; (3) flatness of flank—another feature easy to control; (4) effective diameter—the simple effective diameter which is a plain diametral dimension is the measure of mechanical strength as shown in Figs. 3 and 4.

That the angles and flatness of the flanks can be easily controlled within fine limits is largely due to the increasing use of projection apparatus for magnifying the profile of threads, enabling tool makers to examine their products more closely. This source of error therefore can, for all practical purposes, be considered as negligible, and angle errors may be eliminated from this discussion on interchangeability.

Pitch errors are always present to a greater or less degree, and will have to be reckoned with so long as metals have any elasticity. Also, so long as screws are cut by means of moving machine parts, the allowances or clearances necessary to allow those parts to move will vary under cutting pressure. It will be realised therefore, that apart from the human element there are uncontrollable factors which militate against absolute accuracy in pitch. Pitch errors, no matter how small, have a considerable effect on flank contact. Any difference in pitch between screw and hole not only has to be met by decreasing the effective diameter before the two will assemble, but when assembled together flank contact will only be obtained by deformation of the threads. It is when this deformation takes place that a screw becomes spanner-tight. On the other hand, if a screw is not spanner-tight, pitch difference will cause deformation when the spanner is applied to tighten up. This will be clear from Fig. 5, where it will be apparent that as soon as pressure is applied in the direction of arrow X all the stress will come

Fig. 5. EFFECT OF PITCH ERROR.



on flank 1, although contact had been obtained prior to this on flank *a*. Deformation of flank 1 will take place until flank 2 and subsequently flank 3 obtain contact. Meanwhile the first thread will become more and more deformed as each fresh thread takes up its duties. It is obvious, therefore, the pitch error must be kept within reasonable limits, otherwise the amount of deformation on the first thread will quickly destroy its strength.

The above will suffice to show the necessity for the specification of manufacturing tolerances in the production of interchangeable threaded work. The specification of the actual tolerances and the means of controlling them are matters that need very careful consideration and discussion. It would be mere waste of time to specify such tolerances unless there were some means at hand for easily and quickly measuring the work. The ordinary plug and ring gauge is quite useless for this purpose. If it rejects work there is no means of ascertaining what element or elements of the thread may be incorrect. If it passes work, again there is no means of ensuring that the work is up to standard—it may be much under size. To inspect work adequately by means of plug and ring gauges, at least four separate gaugings are required on each piece of work, namely: (1) Go—full diameter; (2) not go—full diameter; (3) go—maximum full thread form; (4) not go—minimum effective diameter only.

This method of gauging should be supplemented by the use of projection apparatus, for a proportion of the articles produced, say 1 in 50.

A much simpler method of gauging screws, and one that can be applied by the actual machine operator as well as the inspector, is by means of the Wickman adjustable calliper gauge for screw threads. This system has already been fully described and illustrated in these columns.* Messrs. Alfred Herbert, Limited, of Coventry, who supply this gauge, have recently given a large amount of time and attention to this important subject, carrying out numerous experimemts and tests to determine the degree of accuracy with which it is possible to produce commercial screws, nuts and tapped holes. The information they have collated has been placed at our disposal for this article. A large part of it was obtained during the development of the Wickman gauge, but since this gauge was placed on the market, the tests have been, and are still being, continued, with the purpose of ensuring that all screw-making tools for which they are responsible shall be of such a quality that interchangeable products of a definite quality will result. The line of investigation was to determine the degree of accuracy necessary to assure a definite combination of mechanical strength and interchangeability. Coupled with this was a careful scrutiny of the dies and other tools used to discover the faithfulness or otherwise with which their perfections or imperfections were reproduced in the work done by them.

Dealing with the latter part first, though there is still a large amount of work to be done before really definite statements can be made, it has been proved that a tap can generally be relied upon to reproduce its own accuracy of pitch provided it is operated under good working conditions without excessive end pressure and without side pressure. When tapping by machine a good hole can be produced by a good tap, certainly within very fine tolerances. But when tapping by hand using the ordinary tap wrench, care must be exercised to keep the pressure on the tap evenly distributed. All taps should be carefully checked before being put into use, and those which are out of pitch or inaccurate on effective diameter beyond some predetermined set of tolerances should be rejected. Self-opening dieheads can also generally be relied upon to turn out work that will pass inspection provided the tolerances allowed are reasonable.

With regard to the degree of accuracy necessary to assure a definite combination of mechanical strength and interchangeability, the work carried out consisted of a minute inspection of dies, taps, screws and nuts, in quantities of different sizes. Standard dies and taps were used throughout the tests, drawn from stores in the ordinary way so that the result would not be influenced by anything militating against a true representation of commercial methods of production. In many cases the screws and nuts made were cut in half to compare the threads of each with the other. No attention whatever was paid during the whole of the investigations to full and core diameters or radii of crest and root. It was found that these were taken care of in the making of the dies and taps. The chief method of inspection adopted was by means of Wickman gauges in which the front anvils are set to maximum full form diameter and this method was a sufficient check.

The results of this investigation may be summarised as follows:—

1. The majority of screws and nuts produced by ordinary commercial methods are outside the specified British Engineering Standards Association tolerances.

2. In spite of this fact most of such screws and nuts assemble and are strong enough for their purpose.

3. To produce work within the British Engineering Standards Association tolerances requires special care in manufacture and makes the product more costly.

The conclusions naturally drawn from the above results are that the British Engineering Standards Association tolerances are too fine for ordinary commercial work, and that it is desirable to specify grades of coarser tolerances suited to the requirements of the product.

When considering this question of tolerances there are many factors to be taken into account, all of which have a close bearing on the cost of production. In the first place there is the duty the work has to perform. In aeroplane work, for instance, lives may depend on the strength of a screw. Such work should be controlled very strictly both in pitch and effective diameter. On the other hand, rapid assembly and not strength is the leading characteristics of cheap machinery where black bolts and nuts in cored holes and slots are used simply to hold the parts together. It is obvious that while interchangeability is required equally in these two extreme cases, the same quality of work in both would be ridiculous. Production methods vary. One class of screw is made on the highest grade automatic machines with great care and constant attention. Another class must be turned out with the greatest rapidity, with no time available for the care of tools or of the machine so long as the work continues to assemble. An instance of the latter class is the screwed stoppers for petrol cans; there is no margin available for rectification if these should fail to assemble, while quality apart from assembly is clearly of no moment. There are many grades of work between the cases above-mentioned for all of which tolerances of some sort are desirable, but on the face of things the same tolerances are clearly not necessary.

Another factor that affects the permissible tolerances is the pitch error that is invariably encountered in all commercial screw-making under ordinary working conditions. The liability to pitch error is variable and is caused by the amount of slackness that allows all the moving parts of the machine to operate and without which no work could be produced. The liability to pitch error on this account must be accommodated in the tolerances specified. There are, further, the errors of the tools themselves to be taken into account, also the difficulty of exact setting-up to get the correct diametral measurement. In addition there is the general tendency of every workman to make his bolts as large as possible and his nuts as small as possible, to leave room for rectification of rejected work. Last, but not least, there is wear on the tools to be absorbed in the tolerances. An intelligent operator sends his dies to be sharpened as soon as they show signs of being dull, but the majority usually wait to do so till they begin to get work rejected by the inspectors.

Thus it will be seen that the specifying of tolerances for interchangeable threaded work is a totally different matter from the laying down of limits for plain cylindrical work, and if screw thread tolerances seem at first sight to be coarse, they are not so in reality. A concrete case will illustrate this fact which is of the utmost importance. Consider the 1-in. diameter British standard fine thread. The theoretical sizes of bolt and nut are:—

	Bolt.	Nut.
Nominal diameter ...	1 in.	1 in.
Threads, per inch ...	10	10
Depth of thread ...	0·06405 in.	0·06405 in.
Full diameter	1·0000 in.	1·0020 in.
Effective diameter ...	0·9360 in.	0·9380 in.
Core diameter	0·8719 in.	0·8739 in.

The tolerance on effective diameter is 0·0063 in., and this will all be absorbed by a pitch error of 0·0032 in. in the length of engagement (see column 4, pages 18 and 19, Report No. 84–1918). In other words if there is a pitch error of 0·0032 in., the operator must work to a dead dimension of 0·9297 in. on effective diameter on every screw produced to keep within the British Engineering Standards Association standard tolerances. The actual tolerance available for the operator to set up on diameter is only one-quarter of that specified in the table, the other three-quarters being neutralised by errors of tools, wear on tools, drag and pitch variation. In this case, therefore, only about 0·0016 in. is available for setting-up purposes. This on a multi-cutting tool like a dichead is remarkably small, and it requires therefore a very skilled and intelligent tool setter to keep his work within the British Engineering Standards Association tolerances.

(To be continued.)

* See ENGINEERING, vol. cx, page 551.

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LABOUR costs in America have in the past directed closer attention in that country than in our own to the development of labour-saving machinery, and an interesting example of an appliance falling within this class is furnished by the portable elevator, or tiering machine, which it is stated is now being used in more than a hundred different industries in the United States. The piling of packages in warehouses, or sheds by hand involves much heavy labour, and in many cases also involves sacrifice of useful storing space,

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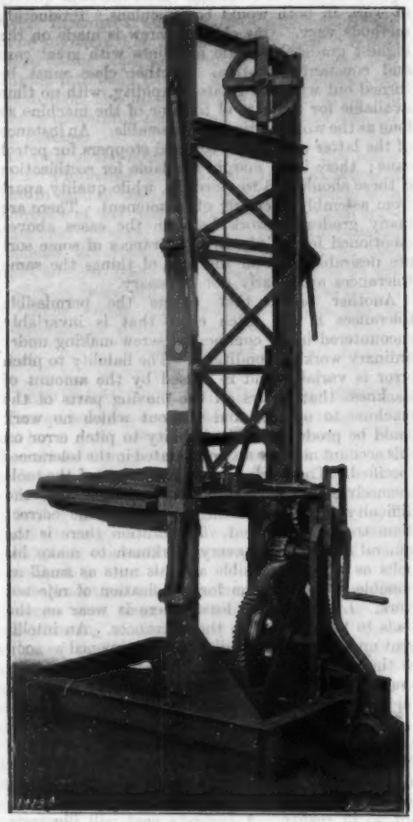

Fig. 1. Hand-Power Tiering Machine.

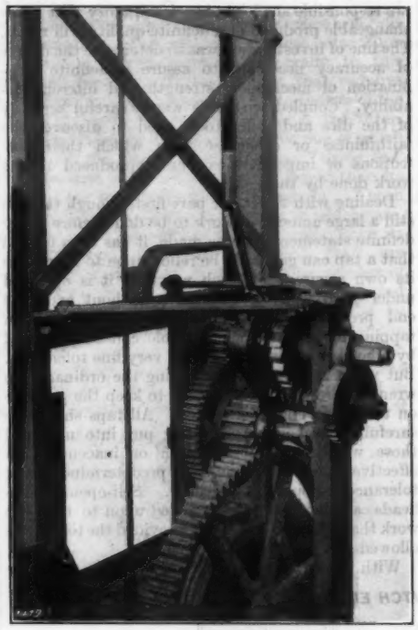

Fig. 2. Detail of Hoisting Gear and Brake.

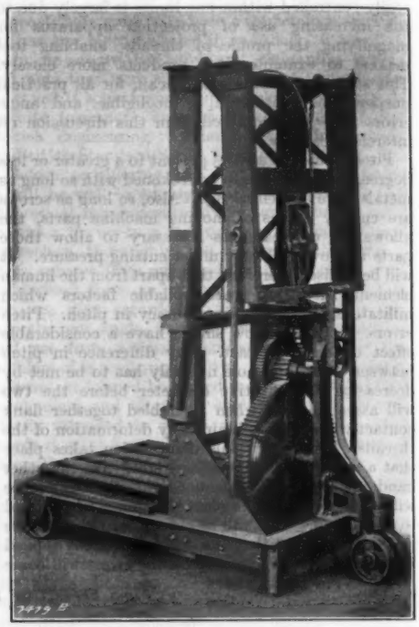

Fig. 3. Tiering Machine with Extension Folded Down.

either because it is occupied by stagings and improvised stairways, or because it is inaccessible by hand methods. Portable elevators are not unknown in Great Britain, but more attention has possibly been paid to their development in the United States, and in this article we propose to describe some of the models developed by the Economy Engineering Company of Chicago. The company has been building tiering machines for over 17 years, and although improvements have been made in the design from year to year, the original machines built are still in service.

In all the machines we are illustrating, the main frame and the base frame are of structural steel, thoroughly braced, and supported at the four extreme corners. This insures stability, and makes the whole structure substantial enough to handle the heaviest case without danger of sliding or tipping over. A lock-to-the-floor device is incorporated in each machine. This is simple, positive, and cannot be neglected, as it works in conjunction with the steering lever, so that it is always automatically in service. It does not require a separate operation to throw it into use. This locking device is an important safety feature. Its method of operation will be understood from the general view of the tiering machine given in Fig. 1, above. When the handle is raised the base frame of the machine is lowered and two feet—one at each corner—grip the floor and hold the machine firmly in place. There is no danger of the machine slipping, and the handle cannot drop and is out of the operator's way. When the handle is brought forward, the wheels engage the floor and the feet are lifted about $\frac{1}{4}$ in. The machine can then be moved around as easily as a truck. When the handle is raised to the vertical position again the machine is automatically locked to the floor and remains there rigidly until the handle is again drawn forward.

The machine is built with a cantilever platform, giving three unobstructed sides, so that a package may be pushed on to the platform at the floor level from the front, and pushed off at either side when the desired height is reached. This construction greatly increases the speed of handling, as it cuts out unnecessary operations. The platform frame is of riveted steel construction, no castings of any kind, except the wheels, being used. The machine shown in Fig. 1 is of the hand-power type, and the hoisting gear incorporates some important features. The gearing is of ample size, easy in ratio to the load, and a "safety first" brake is incorporated, which is specially designed to prevent a "flyback" of the crank, resulting in a bad rap on the arm or a runaway load.

Details of the hoisting gear and brake are shown in Fig. 2, above. The usual crank, ratchet and pawl and hand brake can be seen, but in addition, a friction clutch lies between the ratchet wheel and brake drum, and this friction clutch makes the "Safety First" brake. Whether the load is cranked up or down, the friction clutch in combination with the ratchet, holds the load positively at any point. The ratchet dog is always in engagement whether the platform is going up or down, and it makes any "flyback" of the crank impossible under any circumstances. To lower the load rapidly the friction clutch is released by setting the hand brake and revolving the crank backward about one turn. Releasing the brake gradually then lowers the load at any desired speed. At no time is the crank removed, nor can the load turn it backward, neither is the pawl released or any operation performed other than to turn the crank and handle the brake.

If the machines are to be operated in more than one building, and it is necessary to take them through doorways with clearance less than their operating height, the tiering machines are equipped with folding tops or hinged sections, so that they may be folded over as in Fig. 3. The hinges are placed at any point to suit the requirements. The hinges are steel castings, riveted to the uprights. The only bolts used are the one at the pivot point, and the one that acts as a lock. The bearing surfaces are machine-finished, and when the folding top is in the upright position, as shown in Fig. 1, the hinged sections are locked together by a large wedge, forced into a bolt pin which passes through the top and bottom section of the hinge. The hinges are designed so that when a load is on the machine, they tend to close tighter, and this tendency is increased with the weight of the load. The rods, on the uprights of the machine, are used by the man to raise and lower the folding top. In very high or large-capacity machines these rods are tied into the base frame structure after the top is raised and act as additional braces.

The hand power tiering machines of the Economy Engineering Company are built with capacities from 500 lb. to 3,000 lb., and with various heights of platform lifts from 10 ft. to 19 ft. The platform speed depends entirely upon the capacity, because the gearing is so proportioned that the pressure or effort required on the crank handle is practically the same for all capacities. Due to this, the higher the capacity the slower the speed of the platform, but the effort to raise the load remains the same. The platform speed of a 500-lb. machine is 13·4 ft. per minute; 750-lb. machine is 10·8 ft. per minute; 1,000-lb. machine is 7·8 ft. per minute; 1,500-lb. machine, 4·9 ft. per minute; 2,000-lb. machine 3·9 ft. per minute; 3,000lb. machine, 2·6 ft. per minute. All these figures are on a basis of 60 turns per minute of the crank.

It was found after the hand power machine was developed that there was a demand for an electric driven machine to eliminate the labour necessary to crank the load up to the proper level. Electric-driven tiering machines are now in extensive use where a quantity of materials is to be piled, and where speed is a prime consideration. While the machine is primarily a power elevator, it follows the standard hand-power machines very closely in design. The hoisting mechanism is different, and consists of a set of machine-cut gears, with shafts in babbitted bearings and connected to a low-hung motor by a silent chain drive. This gives a unit that is flexible and of a maximum efficiency, while the weight is close to the floor for stability. Current is brought to the machine through a length of flexible cable provided with a plug which fits receptacles placed at various points in the warehouse or plant. The motor is controlled by a convenient operator's switch, the movement of which automatically opens or closes a powerful brake which holds the load at any point when the current is off. The platform stops automatically at the top and bottom limits of travel. The power-driven machines can be built up to 5,000-lb. capacity, and in all heights to 30 ft., with platform lift speeds of 30, 40, or 50 ft. per minute. Fig. 4, on page 323, is a general view of an electric-driven machine, the gearing, silent-chain drive, operator's switch, low-hung motor, flexible cable and other features can be seen. The electric power-driven machines are also provided with a "safety device" which will catch and hold the loaded platform instantly, should the cable break by accident or wear. This device is shown in Fig. 5, on page 323. Through a system of levers connected to the hoisting cable, a pair of hardened steel cams, surfaced with teeth, are pulled by a heavy tension spring against the channel uprights when the cable breaks. The weight of the load causes the cams

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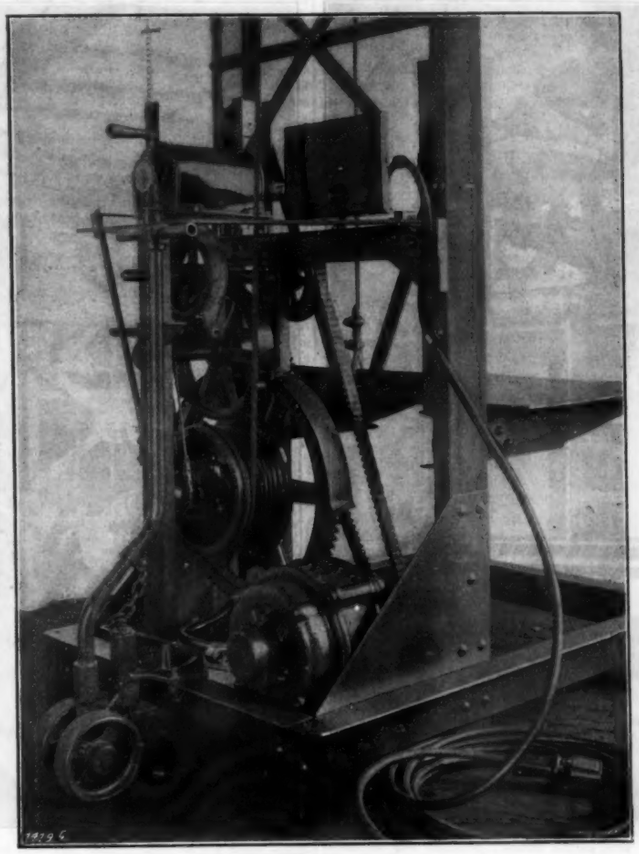

FIG. 4. ELECTRICALLY-OPERATED MACHINE.

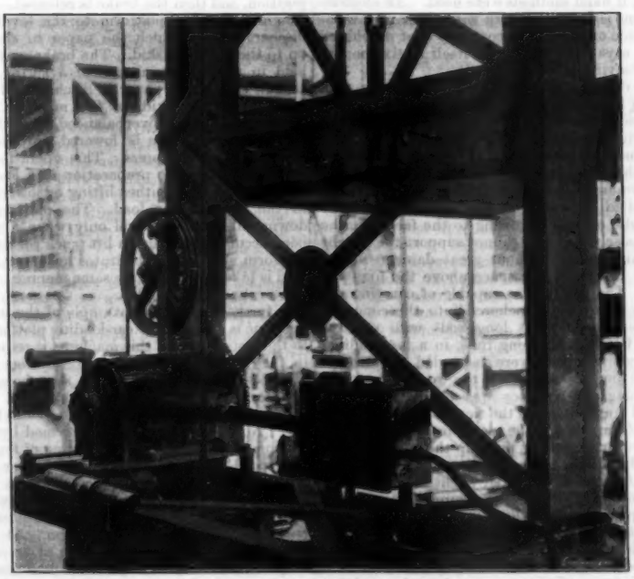

FIG. 5. SWITCH GEAR AND SAFETY DEVICE.

to turn farther and grip the uprights firmer. When the cable has been repaired, the upward pull releases the device and the machine is ready to go into operation, all parts being adjusted for the next possible break.

The Economy Engineering Company has spent a considerable amount of time and money in developing special attachments for their machines. Under this class comes their hand rope control, push button control and selective level automatic stop. These additions to the tiering machines are the same as accessories for an automobile, they are not necessary to make the machine run, but they do improve it and make operation easier. For instance, a "hand-rope control" may be fitted, which permits a man riding on the platform to start and stop it at will, thereby making it possible for one man to raise or lower packages instead of requiring two. The other man would formerly have been stationed on the floor to start and stop the machine by means of an operator's switch. The hand rope control is very simple; a sheave mounted in a bracket is placed, one at the base of the machine and one at the top of the machine. A cable passes over these sheaves and takes a complete turn around another sheave located near the operator's switch, as shown in Fig. 5. This sheave is connected to the switch by a roller chain and sprockets. A lever and spring make it impossible to give the sheave more than half a turn, which is all that is required to start the platform up, down, or to stop it.

Another important feature and one which saves time on each operation, is the selective level automatic stop. If the tiering machine is to be used to elevate materials to predetermined levels, it should be equipped with this device. The three important parts of this device are: the contact mounted on the platform; the electric switches or stations mounted on the uprights; and the selector dial which predetermines the station at which the platform will stop. The automatic stopping of the platform at predetermined levels is effected by so wiring the stations, that when the platforms get to the station selected on the dial, the platform contact engages a roller on the station and breaks the motor circuit. The selector dial has numbers corresponding to the various levels, or stations. With the indicator set at a certain number, the platform will stop automatically at the station or level corresponding to that number. Starting up and starting down are controlled by the usual operator's switch. The brackets holding the stations on the uprights are fitted with long slotted holes, and each station is connected with the conduit by a short length of flexible cable to allow for 1-in. or 2-in. adjustment in either direction.

Push button control has some advantages over the hand rope control, and a number of the new electric driven tiering machines are being ordered with this feature. The push-button control can be put on any electric machine and, if desired, the machine can be controlled from the platform, from any height of pile, from the floor, or all three places. Remote control by means of flexible conductor can also be arranged. The push-button control, while somewhat more complicated than the hand-rope control, or operator's switch control is still sufficiently simple to permit necessary repairs or adjustments to be made by the average workman. Up and down travel and stopping of the platform are controlled by push buttons, the operator's switch being replaced by contactors which make and break the circuit. This control system is made by the Monitor Control Company, Baltimore, Maryland, but was adapted to its present use on tiering machines by the Economy Engineering Company.

All electric machines so far dealt with are intended to operate from a power line, and are known as heavy duty machines. The makers of these machines, however, also manufacture a portable elevator or tiering machine called the "Little-Lifter," which is illustrated in Fig. 6, on page 324. The most attractive point about this machine is that it operates, or rather obtains its power, from the lighting line through an ordinary 660-watt socket. If a light socket is not available, without making any changes in the machanism the platform can be raised or lowered by hand power the same way as would be done with the standard hand-power machine. The "Little-Lifter" type is built up to 1,000-lb. capacity with a ¼-h.p. motor or 1,500-lb. capacity with a ½-h.p. motor. A 500-lb. capacity machine has a platform speed of 12 ft. per minute, a 750-lb. capacity has a platform speed of 10 ft. per minute, and the 1,000-lb. capacity has a speed of 7 ft. per minute.

To operate this machine the operator turns a snap switch which starts the motor, which runs continuously in one direction. After the platform is loaded, the clutch is thrown in and the load elevated to the desired height; throwing out the clutch stops the platform but not the motor, the motor being stopped only when the machine is going to be idle for a long time. To lower the platform, the operator uses the gravity brake, by means of which the maximum load can be lowered at any speed. The load can be positively held at any point of ascent or descent, and the platform cannot get beyond the control of the operator. An automatic stop device limits the platform travel at the top, the bottom limits being taken care of by the gravity brake. This design was brought out to meet the demand for a machine to do work that it was possible to do with a hand-power machine, but where the volume of work

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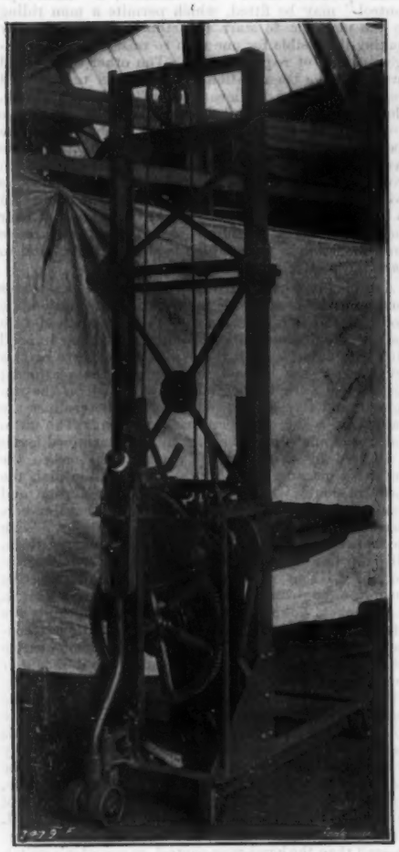


FIG. 6. SMALL-SIZED POWER OPERATED MACHINE.

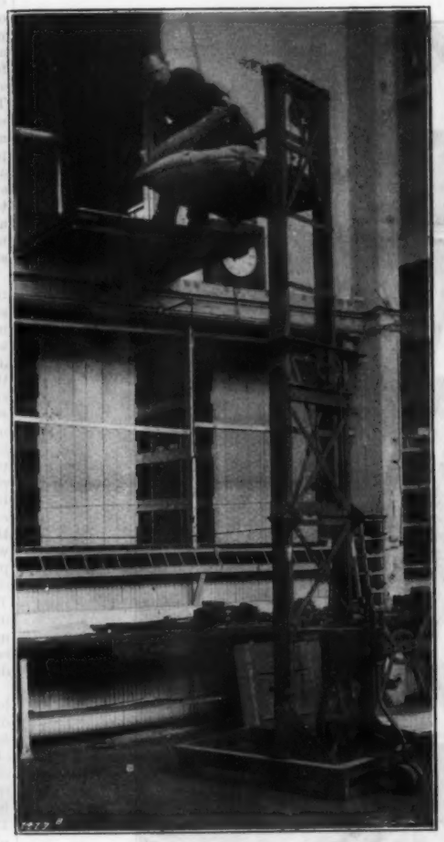


FIG. 7. TELESCOPIC MACHINE EXTENDED.

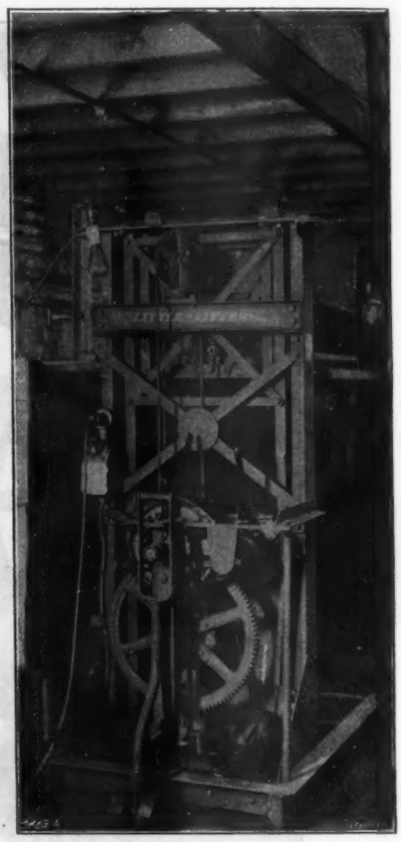


FIG. 8. TELESCOPIC MACHINE COLLAPSED.

made speed of importance, and where a heavy duty electric machine would have been too expensive and too heavy for the work.

The same firm has recently introduced a telescoping tiering machine, which does away with the hinged top section, but which will operate under any ceiling height between two given extremes. For example, a machine 8 ft. minimum height will operate up to a maximum of 13 ft. at any intermediate point. A hand-power machine of the telescopic type in an electrical supply shop, is illustrated in Fig. 7. The machine is operating at 15 ft. or maximum height, the platform elevating to a point 13 ft. from the floor. This is accomplished by an arrangement of sheaves. The minimum height of this machine is 9 ft. 6 in., with the platform 7 ft. 6 in. from the floor. A telescopic tiering machine of the "Little-Lifter" type at its lowest or minimum height, with the platform elevated to the limit of its travel within the inner set of uprights, is shown in Fig. 8. After the platform reaches this height and it is required to pile materials higher, the telescoping or inner section, carrying the platform, elevates automatically to approximately 60 per cent. more than the minimum height. There is no hinging in either set of uprights. Under ordinary conditions, hinges have been found unnecessary.

In addition to the standard machines with which we have been dealing, the Economy Engineering Company have also built many special designs to suit special conditions. The field for special machines is almost as large as the field for standard machines. Referring to the actual employment of tiering machines, reference may be made to an electric-driven machine tiering boxes in a cold-storage warehouse. The company owning this machine states that with it three men are now doing the work which formerly required nine. At the rate of 30 cents per hour and an eight-hour day, this means a saving of $21.60 per day. In another case of piling barrels, it was necessary to add three men to the piling gang for every tier above two. In other words, to pile barrels five tiers high would require from 12 to 15 men, if hand methods were used. An electric-driven machine is doing the work with three men without loss of space or time. The company that purchased this machine says that it paid for itself in six months and now the savings are clear profit.

In another case a machine paid for itself in a month by increasing storage space. The machine is electrically driven and has a capacity of 5,000 lb. In order to give good rigid support on the floor, due to the large capacity, adjustable hand wheel jack screws are used as legs, on the two outward corners. The platform consists of two arms without the platform plate. The material handled is paper. It was impossible to pile it higher bundle on bundle, owing to the fact that the bundles are loosely tied and cannot support the weight incident to high piling without great damage to the bottom tier; therefore, the space above the first pile was wasted. The ceiling was capable of carrying the load, so hook irons were anchored into the concrete, and from these hook irons long rods with stirrups were hung. Between the long rods, in a longitudinal direction, wooden supports were suspended, the stirrups on the rods fitting into a notch in the wood support, to prevent slipping. The paper was piled on wooden platforms and transported to the tiering machine by an elevating platform truck; the platform of the machine consists of two arms, which pick up the wooden platforms from the truck. The tiering machine motor is started and the load is elevated slightly higher than the final position. The wooden supports are then slipped into place and the load lowered to rest upon these supports, and the machine is then moved to another location.

Another special use of the tiering machine is as a gravity-lowering machine. A counterweight is fitted of just the right poundage to slightly more than offset the weight of the platform arms, and an elevating or lift truck platform skid. This machine is used in conjunction with press work, its operation being as follows:—An empty platform skid is placed on the arms of the machine when they are in the lowest position, and then the brake is released. The counterweight raises the platform to the level of the press discharge, from which the paper in sheets is loaded on to the platform skid. The brake on the machine is held in position by means of a spring, and when a certain amount of paper is discharged from the press to the platform skid on the machine, the counterweight is in turn overbalanced, and the load under control of the brake is lowered until level with the feed board of the press. This operation repeated at intervals during the preparation of a load avoids the labour involved in either lifting or lowering each sheet to the level of the load. The platform reaches its downward limit of travel only when a maximum has been accumulated, then a lift truck removes the loaded platform skid, and substitutes an empty, and another load is taken care of in the same manner. The machine has a capacity of 500 lb.

A further interesting example of the use of a tiering machine is as a railway car-loading platform. Previous to the installation of this machine, it required four men in the car and two men outside the car to load a car of goods. The operation was slow because all goods had to be lifted into the car by hand and the men inside the car had to carry each piece to the end of the car. Now the operation is performed by two men and the machine. This makes a saving of four men's time, and speeds up the operation over 50 per cent. There is an overhanging or extended platform to bridge the gap between the machine and the railway car. The operation is as follows:—The trucker pushes the loaded truck on to the machine platform. At this time the overhanging platform is standing at an angle, one end hinged to the machine platform and the other resting on the edge of the car floor. The trucker throws the electric switch, and the platform raises the load to the height of the car floor, stopping automatically at this height. The overhanging platform operating in and out of the car automatically with the action of the machine platform is always in position to form a runway over which the loaded truck is moved into the

car and to the point of unloading. An empty truck, the one previously unloaded, is run on to the platform for lowering. The trucker again throws the electric switch, lowers the empty truck, and the machine is ready to repeat the operation.

Final reference may be made to a special tiering machine built into a machine operation. Previous to the installation of this machine, in conjunction with a tumbling barrel in a nut factory, the nuts were dumped from the tumbling barrel into the pit beneath, and were shovelled from the pit into wheelbarrows and then hauled to a storage bin. The machine is equipped with a hopper car mounted on wheels. The platform of the machine has two arms which, when lowered, fit flush with a track in the pit. A dolly with flanged wheels and carrying track rails runs on to the platform arms. The operation is now as follows:—The hopper car is run on to the dolly tracks, the dolly being held by the tiering machine platform arms. The operator throws the electric switch and the tiering machine platform arms are lowered, the dolly and hopper car are pushed under the tumbling barrel. The nuts are dumped direct into the hopper car and the dolly and car are then pushed on to the platform arms and the load is elevated to track level. The hopper car is pushed off the dolly on to tracks which run over the storage bins. When the load is over the right bin a slide is drawn and the load is dumped, the car returning to repeat the operation. This machine increased production by 75 per cent. and the work is done now by one man instead of six. The operation is performed more quickly and there is no delay.

INDUSTRIAL NOTES.

AT the meeting of the Trades Union Congress at Southport on Wednesday of last week, Mr. Pollitt, of the Boilermakers' Society, asked what steps had been taken to prevent any coal from being shipped from England to America during the miners' strike in the latter country. To this, Mr. H. Smith, of the Miners' Federation, replied that as soon as the American miners' dispute broke out they got into communication with the American miners and asked if anything could be done. They received nothing until August, and they then took the matter to the Miners' International for decision. He asked Congress to remember that whilst the American miners were supposed to be on strike, they were producing more coal in America than the British miners who were working. One hundred and fifty thousand miners continued at work and produced over 5,000,000 tons per week. It was this that defeated the American miners. In any action it was necessary to consult the railwaymen and transport workers, and the difficulties were greater than was perhaps realised by the communists when they made their speeches in the market place. The Federation sent 10,000*l.* to America, and would have sent more had this been possible, added Mr. Smith, notwithstanding another statement of his to the effect that "British miners went through an episode last year which absolutely unhinged their society . . . and the (British) miners were down and out, and were starving."

The Congress meeting of the 7th inst. was taken up largely by discussions on unemployment, the arguments being generally of a political nature. A resolution which was carried unanimously called upon Government to start immediately national schemes for enabling the unemployed to maintain themselves in reasonable comfort, providing, on the other hand, in the case of those for whom no work can be found, adequate maintenance (*a*) by regulating national or local work so as to give employment during seasonal or local fluctuations of trade; (*b*) by organising schemes of useful work and training, with full maintenance for all workers who cannot find suitable employment; these said schemes, of work, training and maintenance, to be made a national charge and not to be placed upon local rates, which impose an undue and inequitable burden upon the resources of poor districts.

At the meeting last Friday, Mr. Swales, of the Amalgamated Engineering Union, moved a resolution the object of which was to amend the Standing Orders and to provide that the General Council be kept informed of all disputes by the affiliated unions, the General Council not to intervene so long as there was a prospect of the differences being amicably settled by negotiation. Should a breakdown occur, or should large bodies of workers be involved in a stoppage, or, again, should standard wages or hours be imperilled, it was proposed that the General Council should take the initiative by calling representatives of the unions into consultation, and use its influence for bringing about a just settlement. The resolution further stated that in cases where the Council intervened and where the unions involved accepted their assistance, should—in spite of their efforts—the policy of the employers enforce stoppage by strike or lock-out, the Council should organise all moral and material support that the circumstances of the dispute justified. The General Council, if necessary, could raise funds by a call upon the affiliated unions proportionately to the membership, in order to meet the expenditure in relation to the dispute. The resolution was shelved; it was opposed by practically all the delegates of the larger unions. The Congress closed last Saturday.

The third annual Lecture Conference for Welfare Supervisors organised by the Industrial Welfare Society is being held at Balliol College, Oxford, from to-day to the 20th inst. This year the conference is open to both men and women, special arrangements having been made for the women delegates. The session is to be opened this evening by Mr. J. W. Pratt M.P., Parliamentary Under-Secretary for Scotland. The programme, which is of a very practical nature, will deal with such subjects as "Welfare under the Whitley Principle," "The Employment Department: Its Functions and Personnel," "Health, First-Aid, Safety." On Sunday forenoon, Mr. Frank Hodges, J.P., Secretary of the Miners' Federation of Great Britain, will give an address on "Health and Welfare in the Mining Industry." Dr. H. M. Vernon, of the Industrial Fatigue Research Board, will speak on "Record Keeping and Statistics." Other lectures will be "Canteens," by Mr. Arthur F. Agar, and "Superannuation and Pensions Schemes," by Mr. J. H. Robertson. In addition there will be a series of short practical papers by supervisors, sectional meetings, and a special session for women. All inquiries regarding the conference should be addressed to the Industrial Welfare Society, 51, Palace-street, Westminster, S.W. 1.

The Board of Conciliation and Arbitration for Manufactured Iron and Steel Trade of the North of England now ceases to exist, owing to the northern employers having joined the national employers' organisation. The Board had been in existence for over fifty-three years. In the course of his address at the meeting in Newcastle winding up the Board, Mr. Reay, the chairman said he and other employers sincerely regretted that this should come to an end after the pioneer work it had carried out during the last half-century. The Board had been the means of producing harmony in the industry, and very rarely had they had to call in the service of a referee. The employers, however, were agreed that the change to the more centralised system of dealing with matters appertaining to the industry would be a change in name only, as those matters would henceforth be dealt with by practically the same employers and employees as heretofore. Instead of there being several organisations in the industry, there would now be only one. He felt that if after the Conciliation Board had come to an end, they carried forward its traditions in an honourable manner, the good fellowship and good understanding of past years would be maintained in all negotiations that might have to be entered upon.

It is reported that negotiations are proceeding for the amalgamation of the National Union of General Workers, the National Amalgamated Union of Labour, the Municipal Employees' Association, and the Transport and General Workers' Union.

The Central Committee of the Shipbuilding Employers Federation met on Tuesday, at Edinburgh, representatives of the shipbuilding trade unions in order to discuss together the critical position of the industry and the means to be taken to secure orders. Colonel James Lithgow, president of the Employers' Federation, was chairman on behalf of the employers, Mr. John Hill (Boilermakers) acting in the same capacity on behalf of the unions. At the close of the meeting a statement was made to the effect that a mutual agreement had been arrived at to adjourn for one month so that the trade union officials might confer with their members. The point discussed, we understand, was the withdrawal of the remaining 10*s.* of the 26*s.* 6*d.* war bonus.

The second quarterly report, from March 27 to June 24, now issued by the Associated Blacksmiths' and Ironworkers' Society, states that the unemployed members now number approximately 7,500, equal to 41 per cent. of the membership. The total income for the quarter under review was 49,747*l.* 17*s.* 3½*d.*, including a sum of 43,213*l.* 18*s.* 5*d.* from the Ministry of Labour for State Unemployment Benefit. The total expenditure amounted to 59,904*l.* 16*s.* 7½*d.*, including 41,321*l.* 9*s.* 2*d.* for State Unemployment and Dependents Benefit. The report adds that with respect to management expenses, these were being carefully criticised and in two items alone, of printing and delegations, the reduction effected, compared with the last quarter, was 594*l.* 12*s.* 5*d.* During the quarter, the society called up investments to the amount of 10,000*l.*, which went to reduce the society's indebtedness to the bank.

Some months ago members of the Amalgamated Society of Woodworkers refused to hang doors and put in window sashes which had been manufactured for a Government Department, in connection with the housing scheme, by Lord Roberts' Memorial Workshops. Correspondence was thereupon exchanged between the committee of these workshops and the union, following which a deputation from the union visited the workshops to see the conditions under which the ex-service men manufactured the material. As a result of this visit the ban upon this has now been removed. It may be noted that 62 per cent. of the men are one-armed men, and their manufactures are sold to the trade in competition with firms who employ able-bodied men. We referred in a former issue (see ENGINEERING, vol. cxiii, page 792) to the difficulty which had arisen at the time.

In a report issued by Mr. Philip Gee, 40, King-street, Covent Garden, W.C. 2, it is stated that the new arrangements for the loading of coal cargoes at the north-eastern ports, under which 2 hours' overtime are worked at the end of the second shift, is not proving a success. Congestion of the docks has undergone no appreciable relief; in fact, the conditions are so unsatisfactory that a considerable amount of trade is being diverted from these to other ports. In the circumstances, it is likely that a further attempt will be made to induce dockers' representatives to agree to a reversion to the three-shift system. When the two-shift system was introduced during the war, it was provided that there should be a return to the old arrangement if the volume of trade justified such a move. It is undeniable that the time has arrived for the change. Thousands of tons of shipping are being held up, thereby incurring heavy losses in demurrage, the staiths are being worked at full pressure during the 18 working hours sanctioned by the men's leaders, and the sidings are crowded with laden coal wagons which cannot be moved. The result of this congestion has already been felt at some of the collieries, which have been forced to close down temporarily owing to wagon shortage. The aggregate loss to the miners in wages is very considerable, and their resentment against the attitude of the dock workers' officials can well be understood.

Although industrial disputes in Pennsylvania in the first six months of this year numbered only 257, outside the coal, railroad and printing strikes, a very favourable showing as compared with any of the past four years, the loss in wages, says *The Iron Age*, New York, greatly exceeds that of any of these years, according to a report by the Bureau of Mediation and Arbitration, Pennsylvania Department of Labour and Industry. For the first six months of the year, strikers in Pennsylvania lost in wages a total of 117,546,466 dols., this being exclusive of the railroad shopmen's strike, which did not begin until the end of the period. Striking coal miners are estimated to have lost a total of 114,502,914 dols. Adding the further losses since June 30 makes a total approaching 200,000,000 dols. In 1921, in 1,210 labour disputes, the strikers lost in wages 38,375,104 dols.

NATIVE MANUFACTURES OF TEXTILES IN CANTON.—Goods produced by Chinese manufacturers are gradually replacing the imported articles in various parts of the southern provinces, says the Chinese Government Bureau of Economic Information. In Canton, the cloth turned out by native looms is ousting the foreign-made cloth. The home-made cloth lacks the fine quality and neat appearance of the imported material, but it has two advantages over the latter—its price is only half that of the foreign-made cloth, while its quality is such as to stand much longer wear than imported goods. Imported cotton hosiery has been entirely replaced by the native-made article in the southern city. Within recent years, hosiery factories have increased considerably, and thousands of women and girls are employed in the work. This has done much to improve the economic condition of the lower class Cantonese, for a skilled hand earns as much as 10 dols. a month. The new employment is so attractive that middle-class women are working in the factories. The demands of the Cantonese for towels were once entirely supplied by Japanese manufacturers. The Japanese towel of the "deer" brand particularly caught the fancy of the Cantonese in former years, but since the boycott days, the people have been turning more and more to the home-made article. It is estimated that about 70 per cent. of the Japanese imported towels have been so replaced in Canton, which now produces enough goods, not only for its own consumption, but also for export to neighbouring provinces such as Kwangsi. The Chinese manufacturers are labouring under serious difficulties in their competition with foreign goods on account of the lack of certain chemical agents in bleaching and dyeing their raw material. For these particular dyestuffs, they have to depend on imports from other countries.

THE FLOW OF STEELS AT A RED HEAT.

*Some Experiments on the Flow of Steels at a Low Red Heat, with a Note on the Scaling of Heated Steels.**

By J. H. S. DICKENSON (Sheffield).

PART I.

The Flow of Steels at a Low Red Heat.—Recent developments in chemical engineering, particularly the growing importance of synthetic ammonia production, have called for the provision of metallic containers capable of withstanding considerable stress at elevated temperatures, and for long periods. Investigation of the mechanical properties of steels and alloys in the heated state has therefore become a matter of very direct practical consequence, and has, for some time past, received much attention in the Research Laboratories of Messrs. Vickers, Limited, chiefly in relation to definitely stated conditions of service.

The published data available almost invariably consist of graphs in which tensile test results, "tensile strength," reduction of area, elongation per cent., and so on, are plotted against the temperature at which the test was made, great care being taken to eliminate the disturbing factor of time by carrying out each test under as nearly the same conditions of heating and loading as possible, the duration of each test being usually relatively short, at most a few hours, with an actual loading time of a few minutes. A series of curves obtained in this way is given in Fig. 1. It cannot fairly be claimed that such information gives more than a general indication of the relative ability of different materials to meet the working conditions usually encountered by the exhaust valve of an aero-engine, or the retorts, catalyst tubes, and so on, of the chemical engineer. It certainly does not enable a designer to construct a container which can confidently be depended upon to maintain shape indefinitely at some high temperature, above a low red heat, when in a state of stress. This is, after all, the practical requirement; that the container, or valve, or whatever else it is, shall not suffer so much deformation that failure takes place, or renewal is necessary, in less time than is economically permissible.

In actual fact all the steels which the author has investigated behave very much like highly viscous fluids at temperatures well below the critical range and cannot be said to have any definite strength at a red heat. Thus statements, actually made, in more or less official reports, to the effect that (*a*) A high-speed steel has tensile strength of 20·1 tons per square inch at 650 deg. C., or that (*b*) a 0·38 per cent. carbon steel has a tensile strength of 39,950 lb. per square inch at 550 deg. C., are not only meaningless, but may be misleading. Either steel would stretch continuously, and finally break, under much less load, if given time.

It follows that the property of principal importance to the engineer who wishes to subject highly heated steel to stress is the equivalent of the viscosity of a fluid.

For the solution of a problem of immediate practical importance the author was content to ascertain, for each of a selection of steels, that temperature at which the rate of flow does not exceed a very small, and practically negligible amount, under a uniform stress of 8·5 tons per square inch, these experiments being described in the following sections.

It should be observed that the influence of the rate of straining, on the stress required to produce fracture of very soft steel at high temperatures, was examined by Rosenhain and Humfrey in 1913, and was referred to by Rogers in that discussion, so that the author would have hesitated to raise the matter again had not the necessity for this been, unfortunately, so apparent.

The selection of material for highly heated and stressed containers, &c., is dependent upon a further factor, the resistance of the heated metal to the attack of hot gases or chemical substances. Cases do, however, arise when the possible bad effect of hydrogen, ammonia, and other gases has to be considered.

The author pointed out that the several series of experiments dealt with were commenced at different times, and in connection with distinct inquiries, so that although a similar selection of typical steels has been made in each case, the corresponding samples of two different series are not always from the same cast. It is considered that this will not affect the usefulness or validity of certain comparisons made.

The Behaviour of a Series of Typical Steels when subjected to rapidly applied Tensile Loading at Temperatures ranging between 15 deg. and 1,000 deg. C.—1. The test-pieces were machined, after the heat-treatment stated below, from rolled bars having the analyses given in Table I.

2. The tensile test-pieces were machined to give a parallel length of 4 in. by 0·564 in. diameter, the nichrome-wound silica heating tube having a length of 6½ in. They were shackled in an ordinary 50-ton Buckton single lever machine and steadily heated. The heating period varied a little between 20 minutes and 30 minutes, but on arriving at the desired temperature each piece was carefully maintained at that temperature for 10 minutes. It was then broken exactly in the usual way, so that the total period of loading occupied only about 1 minute to 2 minutes. At first, efforts were made to observe a yield point by the fall of the beam, but the results obtained were very erratic, and are not here given. In view of the shortness of the heating period, and the relatively large size of the test-pieces, no effort was made to avoid oxidation at the higher temperatures, while the entirely arbitrary character of the test made it appear unnecessary to seek uniformity of temperature along the entire gauge length, by specially arranged winding, to compensate for the end cooling, as described by Bengough. For the purpose of such comparisons as are provided by the present series of tests, it is probable that the ductility would be satisfactorily indicated by the elongation per cent. on the middle 2 in., in spite of a fall of temperature from the middle of the gauge length outwards; but in any case the reduction of area, which is perhaps the better ductility index, is used in comparing these results with those of the series of prolonged tensile tests described further on.

3. The test results set out in Table II, give the maximum load; results of each steel, except those of the 0·45 carbon steel, being plotted in the diagram, Fig. 1, against the temperature. This diagram also shows two characteristic reduction of area curves, those of the 0·30 per cent. carbon and high-speed steels, as well as the maximum load results obtained from a rolled bar of nickel chromium alloy, containing 65 per cent. Ni and 12 per cent. Cr.

Beyond observing that these results compare fairly well with most of the published determinations of "tensile strength" at high temperatures, it is not proposed to discuss them in this section, but to consider them at a later stage, along with those of the prolonged tensile tests dealt with in the next section.

Prolonged Tensile Tests at Constant Load and Temperature.—1. The experimental work dealt with in this section was commenced in the Vickers Research Laboratory in connection with the manufacture of a number of large catalyst tubes for a synthetic ammonia process. These tubes were to be maintained at a temperature of about 600 deg. C., under an enormous internal pressure, a long mean life of tube under these very severe conditions being essential to the economic success of the process.

After consideration it was decided to make them of a nickel-chromium alloy, known to possess high resistance both to oxidation and deformation when under stress at high temperatures, but meanwhile to carry out some laboratory trials to ascertain the precise behaviour of the alloy when maintained for considerable periods under the conditions of stress and temperature existing at the bore of the tube in operation. These prolonged tensile tests gave satisfactory indications, since confirmed by the good behaviour of the tubes in service; but had the matter rested there the results would hardly have interested the members of this Institute. Subsequently, however, it was considered useful to carry out similar tests with a selection of typical steels.

2. *Programme.*—In the first instance one test-piece from each of the selection of typical steels, of which details are given in Table III, was to be kept in tension under a constant dead load of 8½ tons per square inch, and at a temperature maintained as uniformly as possible at 625 deg. C., until breakdown occurred, or until it appeared unnecessary to continue.

Subsequently at least two further tests were to be made on each steel, under exactly the same load, but at temperatures to be determined on the results of the 625 deg. C. test, the rate of extension being determined by overall measurements at suitable time intervals in all cases.

Finally, a tensile test-piece from each steel was to be placed under the same dead load of 8½ tons per square inch, and heated at the uniform rate of 50 deg. C. per 30 minutes, until fracture occurred, the overall extension being measured at short regular intervals.

3. *Selection and Treatment of Test Samples.*—The first five samples set out in Table III were rolled bars, taken directly from the steel warehouse stock, the nickel-chromium alloy samples being cut from a cast 6-in. square crucible ingot.

The question of heat-treatment presented some little difficulty, but eventually it was decided to put the five steels in a tough condition by the treatment shown in Table III, and leave the alloy untreated. With such a series the effect of "normalising" is to produce anything but similarity of initial condition.

It should be observed that four of these steels are of the same casts as the corresponding samples used in the rapid tests, but that the high-speed steel and nickel-chromium alloy samples are of different origin.

4. *Apparatus.*—The apparatus provided for six tensile tests to be carried out simultaneously, as illustrated by Fig. 2, Fig. 3 giving the principal details of one unit, and of the test-piece.

The extreme urgency of the initial experiment made it impossible to wait for the refinement of knife-edges, but the pins were very accurately fitted. A measurement of the load applied by each lever, readily made by compressing copper crusher gauges in a suitable device showed that each lever exerted practically the same pull of between 21 cwt. and 22 cwt., the calculated load

TABLE I.—ANALYSES OF ROLLED BARS.

Symbol.	Class of Steel.	Dia. of Bar.	Heat-Treatment.	Analyses.							
				C.	Si.	Mn.	S.	P.	Ni.	Cr.	W.	V.
		in.										
MC	0·30 per cent. carbon steel	¾	Oil-hardened 850 deg. C., tempered 575 deg. C.	0·30	0·12	0·54	0·027	0·038	0·51	0·14	—	—
HTC	0·45 per cent. carbon steel	1¼	Water-hardened 870 deg. C., tempered 600 deg. C.	0·45	0·37	0·79	0·022	0·024	nil	0·02	—	—
NC	Nickel-chrome steel	¾	Oil-hardened 830 deg. C., tempered 600 deg. C.	0·25	0·11	0·36	0·031	0·026	3·63	0·55	—	—
NR	High-chromium steel	¾	Oil-hardened 925 deg. C., tempered 650 deg. C.	0·26	0·59	0·17	0·066	0·016	0·39	14·68	—	—
HS	High-speed steel	¾	Annealed 800 deg. C. ..	0·62	0·39	0·16	0·053	0·021	0·16	3·98	17·36	0·66

TABLE II.—TEST RESULTS.

Temperature at Time of Loading.	Class of Steel.									
	MC. 0·30 per Cent. Carbon.		HTC. 0·45 per Cent. Carbon.		NC. Nickel-Chromium.		NR. High-Chromium.		HS. High-Speed.	
	M. S. Tons per Sq. In.	R. of A. per Cent.	M. S. Tons per Sq. In.	R. of A. per Cent.	M. S. Tons per Sq. In.	R. of A. per Cent.	M. S. Tons per Sq. In.	R. of A. per Cent.	M. S. Tons per Sq. In.	R. of A. per Cent.
Room temperature ..	43·2	64·8	51·1	64·8	52·8*	66·8	54·0	57·0	54·7	15·0
100 deg. C.	40·4	59·2	47·0	59·2	51·2	64·8	49·9	54·6	55·8	23·0
200 deg. C.	41·8*	55·8	47·6*	60·4	51·0*	62·6	47·2	58·1	52·4	21·4
300 deg. C.	45·6*	51·0	49·2*	53·4	52·4*†	55·2	46·8	57·0	52·8*	32·0
400 deg. C.	40·8	67·8	46·8	69·8	47·0	68·8	44·4	52·2	45·0	27·6
500 deg. C.	27·6	79·4	33·2	83·4	36·0	82·7	38·0	64·4	37·4	32·0
600 deg. C.	20·8	86·1	24·4	84·1	23·2	88·6	27·6	70·7	27·1	58·1
640 deg. C.	—	—	18·5	90·9	—	—	—	—	—	—
700 deg. C.	12·6	92·8	10·4	92·0	13·4	88·6	17·4	84·1	23·0	62·6
800 deg. C.	7·2	99·0	8·2‡	93·4	8·8	96·2	8·8	93·4	13·6	65·4
900 deg. C.	5·1	99·6	4·4	95·2	5·4	95·4	6·4*	91·4	10·4*	75·3
1,000 deg. C.	4·0	99·8	3·4	98·8	3·6	99·9	6·1	91·4	7·2,	80·3

* Broke outside middle 2 in. length. †Actually 310 deg. C. ‡Actually 786 deg. C.

TABLE III.—TEST RESULTS.

Symbol.	Class of Steel.	Dia. of Bar.	Heat-Treatment before Machining Test-Piece.	Analyses.								
				C.	Si.	Mn.	S.	P.	Ni.	Cr.	W.	V.
		in.										
MC	0·30 per cent. carbon steel	¾	Oil-hardened 850 deg. C., tempered 575 deg. C.	0·30	0·12	0·54	0·027	0·038	0·51	0·14	—	—
HTC	0·45 per cent. carbon steel	1	Oil-hardened 850 deg. C., tempered 600 deg. C.	0·45	0·37	0·79	0·022	0·024	—	0·02	—	—
NC	Nickel-chromium steel	¾	Oil-hardened 830 deg. C., tempered 600 deg. C.	0·25	0·11	0·36	0·031	0·026	3·63	0·55	—	—
NR	High-chromium steel	¾	Oil-hardened 925 deg. C., tempered 650 deg. C.	0·26	0·59	0·17	0·066	0·016	0·39	14·68	—	—
VA	High-speed steel	1¼	Annealed 800 deg. C. ..	0·60	0·28	0·23	0·044	0·029	—	3·49	14·09	0·72
CT	Nickel-chromium alloy. Cast	—	—	0·54	0·73	0·10	0·032	0·030	69·90	15·50	—	—

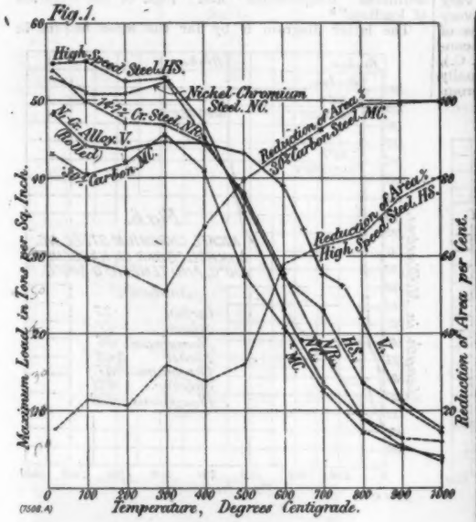
* Abstract of a paper read at the meeting of the Iron and Steel Institute at York, on Wednesday, September 6, 1922.

being 21 cwt. The load on the test-piece may be safely taken as 8·5 tons per square inch in all cases.

The 8 in. by 0·125 sq. in. gauge length of each test-piece was punch-marked along one side in 1-in. lengths, for measurement after fracture, the thermocouple hot junction being held at the middle mark by a small wad of asbestos bound tightly in position by a few turns of platinum wire. This not only prevented movement of the couple during subsequent fitting of the heating tube, but ensured that the couple was actually at the temperature of the test-piece.

The gauge length was additionally provided with two punch-marks, 180 mm. apart, and external to the heating

Fig. 1.



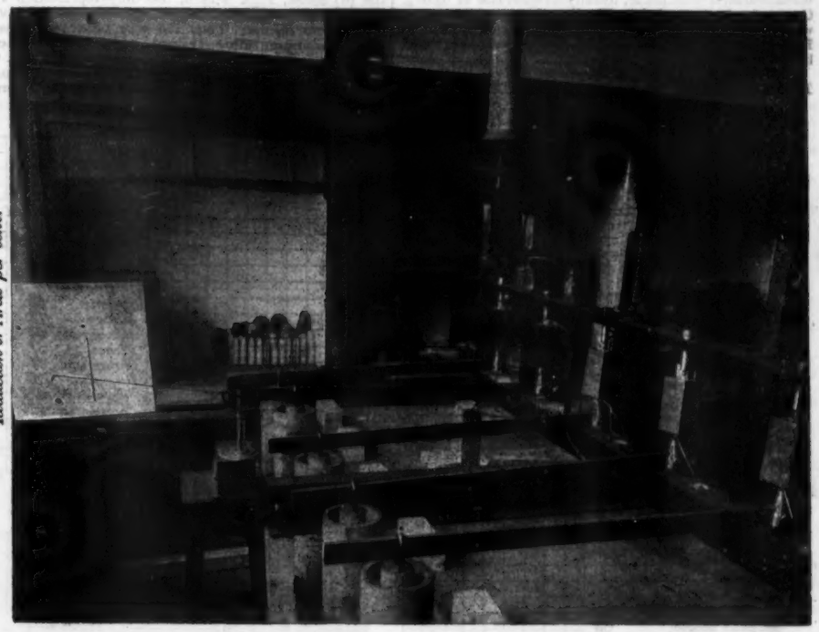


FIG. 2. TENSILE TESTING APPARATUS EMPLOYED.

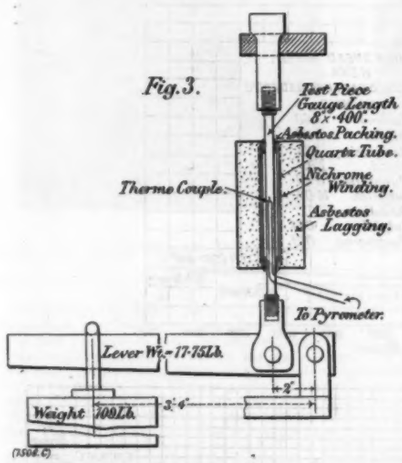


Fig. 3.

furnace, for the purpose of making periodical overall measurements during the progress of the test.

The electric furnaces were wired in parallel, each having a small external adjustable resistance, while the nichrome winding of the silica-heating tube was 110 in. long, in about 45 evenly spaced spiral turns, no effort being made by closer winding towards the ends to compensate for end chilling.

Trial showed that the temperature in the middle 2 in. of the gauge length was not quite uniform, the central point being higher by about 20 deg. C. than the points 1 in. away on either side. The variation in the middle inch was not more than 10 deg. C., but it was deliberately intended that breakdown should occur at the central point, and therefore a little higher temperature was desired.

The annular space between heating tube and test-piece was stopped at both ends by a filling of asbestos fibre and clay, this being constantly repaired when loosened by extension of the test-piece, but no other effort was made to prevent surface oxidation or scaling, which never became excessive, even during the longer runs, since the temperatures were never very high for long periods, except in the case of the relatively non-scaling nickel-chromium alloy.

Finally, the temperatures were recorded by a Cambridge thread recorder, the couples being carefully checked before and after use. No checking was possible during the course of a test, which in one case continued for 6,041 hours, but no appreciable change was found in any instance.

The long duration of some of these trials made a robust and reliable pyrometer far more suitable than a very sensitive instrument, liable to go wrong, and to require frequent checking.

5. *Testing Procedure.*

(a) *Duration Tests at Constant Load and Temperature.*—Great care was necessarily taken in applying the load, the weight being supported while the test-piece was screwed into position, and afterwards most carefully lowered, so that no "live-load" was momentarily produced.

The temperature was then steadily raised to the desired height, where it was maintained day and night, and sometimes for months, until fracture occurred, or it was deemed unnecessary to continue, a daily measurement being made of the distance between the two external (180 mm.) gauge marks.

Naturally more frequent observations were made when called for by rapid extension of the more highly heated test-pieces, or when rupture became imminent at the end of the longer runs.

Owing to current fluctuations, principally those due to meal-time stoppage of machines, it would have been quite impossible to keep the temperature absolutely constant, within, say, 5 deg. C., without unremitting attention and continuous rheostat adjustment.

This was considered both impracticable and unnecessary, but it was found quite possible to keep within a range of 50 deg. C. for long periods, with little or no alteration of the external resistances, and it was therefore decided to run a series of test-pieces from each steel in 50 deg. C. ranges, as 550 deg. to 600 deg. C., 600 deg. to 650 deg. C., and so on. It is utterly impossible to embody the pyrometric records in this paper, over 300 linear ft. of double recorder sheet having been used; but it may be understood that where the temperature range for any given specimen is stated as, say, 600 deg. to 650 deg. C., the mean temperature was not far from 625 deg. C., especially in the longer runs.

In the shorter tests, of less than 100 hours' duration,

TABLE IV.—TEST RESULTS.

1. Type of Steel.	2. Test-Piece No.	3. Temperature Range.	4. Duration of Test in Hours before Fracture or Withdrawal.	5. Time at Load of 8·5 Tons per Sq. In., and Temperature as stated in Col. 3.	6. Elongation on Middle 2 In. per Cent.	7. R.A. per Cent.
			hours			
0·30 per cent. carbon	MC1	500°/550°	1,739. Withdrawn ..	3,400 hours*	—	—
	MC2	550°/600°	956. Broken	956 hours	30·0	85
	MC3	600°/650°	28. Broken	28 hours	29·0	88
	MC4	700° C.	—	3 minutes	32·5	92
	MC	775° C.	—	6 seconds*	—	—
0·45 per cent. carbon	HTC7	500°/550°	1,405. Withdrawn ..	2,600 hours*	—	—
	HTC5	550°/600°	195. Broken	195 hours	32·0	84
	HTC4	600°/650°	26. Broken	26 hours	32·0	84
	HTC8	680° C.	—	3 minutes	33·0	90
	HTC	775° C.	—	6 seconds*	—	—
Nickel-chromium	NC2	500°/550°	701. Broken	701 hours	40·0	85
	NC1	550°/600°	88. Broken	88 hours	41·0	86
	NC4	600°/650°	8. Broken	8 hours	38·0	91
	NC5	695° C.	—	3 minutes	40·0	94
	NC	805° C.	—	6 seconds*	—	—
14·7 per cent. chromium	NR1	500°/550°	1,740. Withdrawn ..	10,000 hours*	—	—
	NR2	550°/600°	1,728. Broken	1,728 hours	34·0	84
	NR3	600°/650°	79. Broken	79 hours	37·0	85
	NR4	735° C.	—	3 minutes	36·0	91
	NR	800° C.	—	6 seconds*	—	—
High-speed ..	VA1/1	500°/550°	1,717. Withdrawn ..	81,000 hours*	—	—
	VA2/1	550°/600°	2,002. Withdrawn ..	25,000 hours*	—	—
	VA2/2	600°/650°	380. Withdrawn ..	4,500 hours*	—	—
	VA3	650°/700°	564. Broken	564 hours	19·0	47
	VA1/2	700°/750°	21. Broken	21 hours	24·0	69
	VA4	815° C.	—	3 minutes	32·0	82
	HS	955° C.†	—	6 seconds*	—	—
Nickel-chromium alloy (as cast)	CT5/1	500°/550°	521. Withdrawn ..	—	—	—
	CT5/2	550°/600°	3,604. Withdrawn ..	108,120 hours*	—	—
	CT1	600°/650°	6,041. Broken	6,041 hours	17·5	40
	CT5/3	650°/700°	901. Broken	901 hours	14·5	23
	CT6	700°/750°	273. Broken	273 hours	27·0	51
	CT8	895° C.	—	3 minutes	24·5	44
	CT4	925° C.‡	—	1 minute	25·0	47
	V	965° C.§	—	6 seconds*	—	—

* Estimated. † Test of another high-speed steel, of similar composition to VA, extracted from Fig. 1. ‡ This was a test carried out in the same way as CT8, except that the uniform heating rate was 100 deg. C. every 10 minutes. It is not elsewhere referred to. § Test of another nickel-chromium alloy, extracted from Fig. 1.

it was not always possible to compensate for a long spell towards the low limit of the range, during a week-end for example, by a corresponding period towards the upper limit.

(*b*) *Tests at Constant Load and Uniform Rate of Heating.*—After the test-piece was placed in position and the load applied, the 180-mm. gauge length was measured. The temperature was then slowly raised, by means of a specially devised rheostat, at the uniform rate of 100 deg. C. in every 60 minutes, an overall measurement being made at 100 deg. C., and thereafter on reaching each additional 50 deg. C., great care being taken to make this coincide with half-hourly periods.

Later, as the rate of extension increased, more frequent measurements were made, usually at each rise of 10 deg. C., in 6-minute periods. Finally, the temperature at which the test-piece ruptured was carefully noted. It should be added that all these test-pieces were pulled by the same lever.

(*c*) *Measurement and Micro-Examination of Broken Test-Pieces.*—After fracture of a test-piece the extension on each (original) 1-in. length was determined, but as almost the whole stretch invariably occurred within the middle 2 in., only the elongation per cent. on this portion of the gauge length is here recorded. The reduction of area at the fracture was always taken, and, in a number of selected cases, a longitudinal half-section was removed to include the fracture and microscopically examined.

6. *Discussion of Test Results.*—Table IV sets out the principal results obtained from every test-piece of the two series :—

(*a*) Constant load and constant temperature, and

(*b*) Constant load and uniformly rising temperature.

It also includes figures, extracted from the smoothed curves of Fig. 1, to show the temperature at which the four steels, M C, H T C, N C, and N R, would rupture under a load of 8·5 tons per square inch, under the loading conditions described for the rapid tests. In these cases the duration at full load, of 8·5 tons per square inch, and at the temperature stated, is estimated at 6 seconds. In actual fact it would not matter very much, as regards the purpose for which this figure is to be used, whether the duration were taken as 30 seconds or 0·30 seconds, but the period in the tensile tests described above between the moment of attaining maximum load and the fracture of the specimen, is certainly well within this range, and probably quite near the 6 seconds stated in Table IV. It is necessary also to state, in the same table, the period during which the test-piece of the series (*b*), constant load and rising temperature, were at the temperature of breakdown. Here a close approximation is possible, the figure given being 3 minutes; the time occupied in rising the 10 deg. C. prior to final collapse of the test-piece; and this duration is not treated as a mere estimate in Table IV. The only remaining estimates in Table IV are those of the probable lives of test-pieces subjected to constant load and temperature for long periods, and eventually withdrawn, stretched, but unbroken. A number of such cases are shown in Figs. 5 to 9, which, each confined to a single steel, show the rate of extension of every test-piece, the plotted results being the actual daily measurements of overall length.

The extension-temperature diagrams of the (*b*) series are plotted in Fig. 4, and show that up to 400 deg. C. all the steels extend alike, the upwards curvature being probably due to falling modulus of elasticity. Thereafter the curves diverge, a considerable amount of flow taking place, in each case, at temperatures well below that finally reached. An interesting departure from the general form of the curves is that of the high-speed steel, but the author has been unable to check this result, which was obtained from the last remaining test-piece of steel VA.

It scarcely requires mention that the diagrams of the (*a*) series, Figs. 5 to 9, not only represent a very considerable amount of labour, but present some very remarkable results. Thus the case of a test-piece of nickel-chromium alloy (Vikro) which extended continuously from the first day of loading (at 625 deg. C.), but only broke after 6,041 hours, and the almost equally surprising extension curve of the 14·7 per cent. chromium steel, which stretched continuously for 1,728 hours before final breakdown, are results little expected by the author at the outset of this work. However, these extension curves will be discussed later.

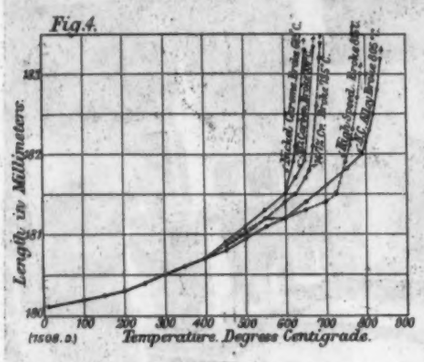
Returning now to the "withdrawn" test-pieces of these diagrams, an estimate of the probable time before rupture would have occurred, had the test proceeded, was obtained in each case by comparing the time required to produce the same extension in unbroken and broken (because more highly heated) specimens of the same steel, the assumption being made that the complete extension-time curves would have the same form in each case. The estimates, which were necessarily obtained from carefully smoothed curves, are given exactly as calculated, but there are good reasons to suppose that the time is, in most cases, an underestimate, and, in any case, these estimates are only of general interest.

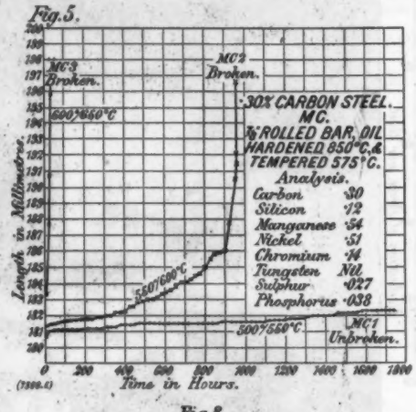
Beyond the general deduction that the temperature attained is higher as the duration at load is shorter, the relationship between these two variables will hardly be perceived from Table IV, but before passing on to consider this data in graphical form, an interesting feature of the ductility results may be noted. It will be seen that in all cases the reduction of area per cent. rises as the test-pieces are more rapidly broken, and that this is sometimes, but not always, accompanied by a corresponding rise in the elongation per cent. The three high-speed steel specimens, broken in 564 hours, 21 hours, and 3 minutes (at load), provide the most striking instance of this combined increase. Probably this is largely due to the higher temperature at which flow takes place, but possibly also the extent of the part played by plastic deformation, as opposed to purely viscous flow, is greater with more rapid loading.

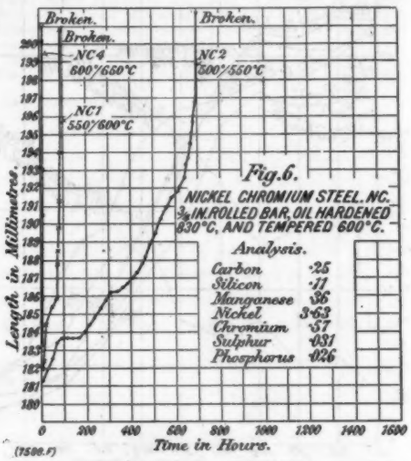
The data of columns 3 and 5, Table IV, are plotted in Fig. 10, having as co-ordinates "temperature" and "duration of loading," and in Fig. 11, having as co-ordinates "temperature" and "logs. of the duration of loading."*

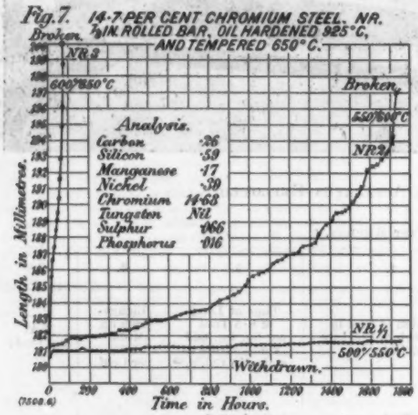
The latter diagram is by far the most helpful in comparing accurately the results of tests varying in duration between 6 seconds and many thousands of hours, but Fig. 10, which scarcely needs explanation, well brings out the enormous influence of time in determining the temperature up to which each type of steel can support a given load (in this case 8½ tons per square inch), and, by implication, the load which can be borne at any given temperature. It is easy to deduce, for example, especially if Figs. 5 to 9 are consulted, that the maximum temperature up to which each of the typical steels will support a load of 8·5 tons varies, with conditions of loading, between the figures given in the table on the next page.

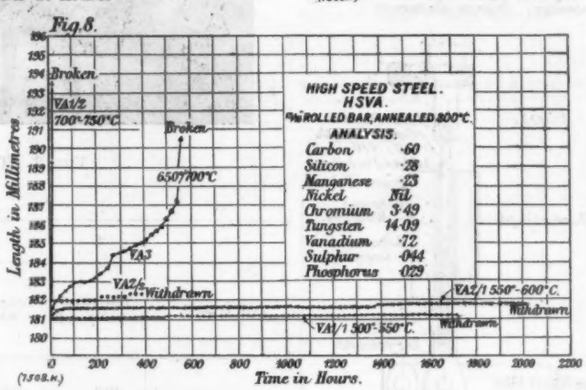
It is largely because results of the type set out in column 1 are those usually published, while working conditions demand the data of column 2, that the author ventures to present this communication, the intention being rather to call renewed attention to the decidedly misleading character of the term "tensile strength," as applied to steel at elevated temperatures, and to throw doubt upon the figures quite commonly

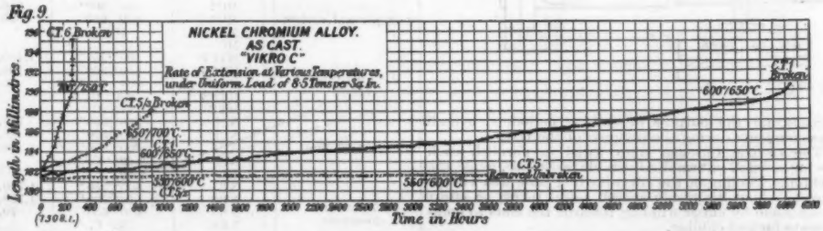












* These diagrams are simplified by the exclusion of the carbon steel HTC.

accepted as representing this doubtful property, than to present a mass of data.

—	1. Under a rapidly Applied Load, or for Short Duration of Loading.	2. When the Specimen is expected to Endure for Considerable Periods without suffering Sensible Deformation.
	deg. C.	deg. C.
0·30 per cent. carbon steel	775	500
Nickel-chromium steel	805	450
High-chromium steel	800	520
High-speed steel ..	955	575
Nickel-chromium alloy	965	600

Fig. 10

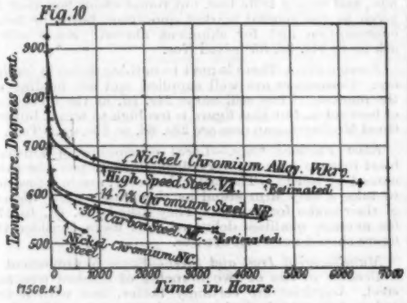
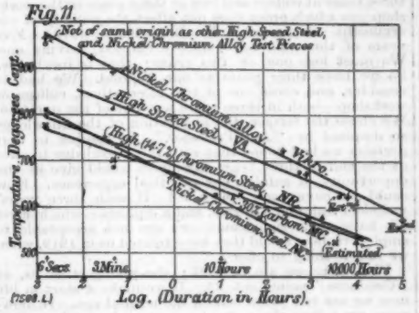


Fig. 11.



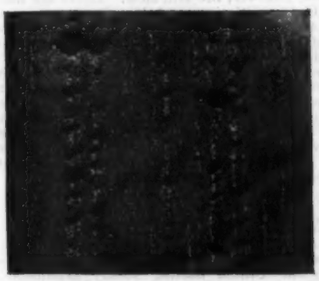


FIG. 12. FRACTURE OF TEST-PIECE VA3. × 100.

FIG. 13. FRACTURE OF TEST-PIECE MC4. × 50.

Naturally the work was of a somewhat laborious character, but having carried out this series of tests at 8·5 tons per square inch the author proposes to put in hand supplementary tests, on the same lines, but at less and greater loads, which should enable an engineer to know exactly how various typical steels will behave under varying conditions of stress and temperature. In the meantime some very useful practical deductions may be drawn from these diagrams, and from Table IV.

The Flow of Steels at a Low Red Heat.—Although all the long-duration tensile tests, described in the previous section, have been carried out at temperatures well below the critical ranges of the respective steels, the form of the curves in Figs. 5 to 9 points very strongly to the extension, and eventual rupture, of the test-piece, under unvarying load, being due almost completely to viscous flow. Whether plastic flow affects the shape of these curves, and if so, whether the data will prove sufficient to enable the plastic to be separated from the viscous flow, is a question to which the author has not yet found an answer; but it does seem that a steady extension, under an unvarying load, such as that of the specimen CT1 of Fig. 9, when a test-bar stretched continuously for 6,041 hours, can only be due to truly viscous flow, with very little of the nature of ordinary plastic deformation entering into the case at all. This test is of a nickel-chromium alloy, but the curves of the various steels (N R 2 of Fig. 7, for example) are little less remarkable, and all are more or less of the same form. It may be noted also that no test-piece which has been kept under stress for more than 1,000 hours has failed to show some movement, and that in some cases specimens which have been loaded for long periods have only stretched a very small total amount, but yet have made the extension in such a way as to suggest very strongly the ultimate formation of a curve of the same form as the others where fracture eventually occurred. N R 1/1, Fig. 7, is a case in point.

At the same time the author must admit that these extension curves, when plotted in terms of their logarithms, do not give perfectly straight lines. It should be borne in mind, however, that, during the progress of a test, the extension of the test-piece gradually disturbs the thermal conditions in the middle part of the gauge length. Further, all the long-duration tests have been carried out at temperatures well below the low limit of their respective critical ranges, so that the steel undergoing deformation is, mechanically, a mixture of harder and softer constituents. Very probably the shape of the extension curves, in these cases, is determined by the differing behaviour of the ferrite matrix and the carbide particles. Also, it should be noted, microscopic examination of longitudinal sections, prepared to include the fracture of ruptured test-pieces, has usually shown evidence of more or less general internal rupture. Whether this only occurs when the elongation has reached such a point that final rupture is imminent, has not yet been determined, but two characteristic cases are shown by Figs. 12 and 13, taken from the vicinity of the fracture of test-pieces VA 3 and MC 4 respectively. The former, taken from a high-speed steel which has broken after 564 hours continuous extension, shows numerous cavities produced along the threads of segregated tungstide globules; while the other, from a carbon steel, actually at the fracture, shows many longitudinal ruptures, apparently produced by the sliding of one plane over another, usually

FIG. 14. RUPTURE OF CAST NICKEL-CHROMIUM STEEL SHOWING MEMBRANES OF CARBIDE BROKEN UP. × 50.

assisted, and perhaps caused, by the presence of particles of non-metallic impurity. In the case of the cast nickel chromium alloy, rupture occurs between the grains of solid solution, where membranes of carbide, broken up into globules, have a decidely weakening effect (Fig. 14).

It is evident that such disturbing factors must make the interpretation of these extension diagrams a matter of very great difficulty, but the author hopes to proceed further with this aspect of the investigation in the future.

However, in spite of all this, and remembering that the points in Figs. 10 and 11 are based on total duration, during which the amount of deformation of the several test-pieces of each steel was not always the same, study of Fig. 11 leads to some quite interesting speculations.

Although the plotted points are too few in number to enable any definite conclusions to be drawn, they certainly tend to fall in straight lines, and making allowance for the disturbing factors previously mentioned, strongly suggest that the samples have behaved in accordance with the law governing the change of viscosity with temperature.

The author is very anxious not to overstrain the data embodied in Fig. 11, but it is a striking fact that the nickel-chromium alloy and the nickel-chromium steel give approximately parallel lines, which are inclined to the lines of the other three steels, these also being more or less nearly parallel.

Whether this difference indicates anything fundamental is not clear, but after all there is a difference in the behaviour of nickel steels as a part from carbon and chromium steels when subjected to tensile stress even in the cold.

Fig. 11 also explains why the nickel-chromium alloy, which has much the same endurance as high-speed steel at 625 deg. C., should be so very much more difficult to forge at 1,000 deg. C., when, under a hammer, it appears to be very much harder than high-speed steel. Much the same remark will apply after a comparison of the 0·30 per cent. carbon and nickel-chromium steel lines. Although the latter material certainly deforms more readily under constant load at, say, 575 deg. C., most forgemen would describe it as the harder steel of the two. One very important practical consideration arises out of this; that in selecting material for resistance to stress at elevated temperatures the nature of the stressing must be brought into account.

Thus, for example, the nickel-chromium alloy is obviously far better able to resist occasional and intermittent heavy loads at high temperatures than is high-speed steel, but at much lower temperatures the latter steel shows equal endurance. It should be added, however, that when resistance to oxidation becomes a factor the alloy scores heavily, but this aspect of the matter is dealt with in Part II. of the paper.

Finally, although the author does not wish to trespass upon the domain of the mathematical physicist, it may be asked, whether, if the lines in Fig. 11 are really straight, the same law will continue to apply down to very much lower temperatures.

If so, there seems to be no reason why a cold test-piece of, say, the 0·30 per cent. carbon steel, should not, in time, be pulled in two by a load of 8½ tons per square inch.

Production of the 0·30 per cent. carbon steel line down to the atmospheric temperature actually comes out at about log. 19 (hours), or roughly one thousand million million years. However, these rather wild speculations are getting far from the original purpose of this investigation.

(To be continued.)

"IMPACT ON RAILWAY BRIDGES."

TO THE EDITOR OF ENGINEERING.

SIR,—Having listened with great interest to the papers read by Messrs. Gribble, Cookson and Nicholas, and Wilson, at the British Association's meeting of Section G. at Hull, last week, one is driven to the conclusion that it would be most illogical for the Ministry of Transport to compel all railway engineers to design their bridges of the future in accordance with the suggestions contained in Colonel Mount's report on "Impact Effect on Railway Bridges," before further and more exhaustive experiments on the subject of impact are carried out.

One of the authors asks for collaboration between the research worker and the maintenance engineer, and it occurred to me that the time is now opportune for a "Bridge Research Commission" to be formed, for the purpose of studying the question of "impact" and matters appertaining thereto.

I suggest that the "Commission" be made up of eminent mathematicians, physicists and engineers, and they be given the power to conduct all experiments and analysis they consider necessary to obtain a scientifically satisfactory solution of the impact question. Also the expenses incurred in carrying out this research be borne by the Government and railway companies jointly.

Yours truly,

September 11, 1922. T. A. B.

STATES AND ENTITIES; WHAT IS ENERGY?

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of August 25, on page 236, "A Constant Reader" pleads ably for clear thinking in regard to a very hard worked term—"Energy." If his remarks are restricted to applied mechanics, there is little objection to his commonsense view of energy as ability to do work, but if he intends to define energy as such ability, I would call his attention to the first requirement of a definition—that it should be inclusive, exclusive and conclusive. In the wide realm of physics, energy has been shown to possess mass, or to quote from your correspondent, to be "endowed with inertia . . . manifesting itself in two forms; matter and radiation," and the terms used in applied mechanics and engineering should not conflict with those used in other branches of physics. I suggest it does clarify thought on this subject to regard matter as a form of energy, a form which Professor Eddington calls "bound" (this applies to the smallest particle of matter—the electron), and to regard radiation as a free form of energy, though it still possesses inertia in this free form—witness the eclipse observations in confirmation of Einstein's theory of relativity. It is in fact this relativity of quantities, particularly in reference to motion, that makes it difficult to reach the precision which "A Constant Reader" rightly desires. The whole trend of modern physics goes to show that energy is more fundamental than matter (it is conserved, whereas matter is not). In physics, energy *is not* "ability to do work," but it *has* "ability to do work" through the manifestation of

"force" when its natural flow is interrupted or when interfered with by other energy. It does not seem possible to speak of the absolute energy of matter since there is no absolute rest or absolute frame of reference, but I suggest we might speak of the intrinsic energy of matter. Potential and kinetic energy are entirely relative terms, and when spoken of, relative potential or relative kinetic energy is implied and understood; but in mechanics it would be carrying precision of statement too far to require the term "relative" to be used.

"Force" is more generally derived from energy than from matter. Some confusion arises in regard to "force" from the mistaken view that matter possesses force (it only possesses ability to manifest force). Newton is largely responsible for this misunderstanding through his law of gravitation which gives the impression that some mysterious force of attraction is inherent in matter. Force is, as already stated, only manifested when the natural flow of energy is interfered with. If air resistance is neglected, an aviator falling to the earth does not experience or manifest force during his fall, but only when his free motion is interrupted by contact with the ground.

It seems that "action" which embraces the four dimensions of space-time should be the basis from which other terms in physics should be derived, and I am sure your readers would welcome some concise definitions arrived at in this way.

Yours faithfully,

AN OCCASIONAL READER OF ENGINEERING SINCE 1910.

"A STANDARD COEFFICIENT FOR PIPE RESISTANCE."

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of the 8th inst., Mr. E. Parry gives a valuable analysis of published data derived from recent measurements of pipe resistance, and draws attention to the inconvenience and disadvantages of the older empirical formulæ in general use, as compared with the Stanton method of analysis, based on the principle of dynamic similarity.

Mr. Parry quite rightly states that this serviceable method of analysis is still commonly neglected in published work on pipe resistance. One reason is, doubtless, that practical engineers fear that the "new" coefficient $R/\rho v^2$ may be none too readily compared with the older coefficients, particularly d'Arcy's factor f and Chezy's coefficient C, so long in general use.

It may be of service, therefore, to point out that the d'Arcy factor f possesses all the advantages of the non-dimensional factor $R/\rho v^2$. The factor f is itself non-dimensional, as is shown by the equation in which it is defined, viz.:

$$\text{Loss in hydraulic head} = f\,(l/r)\,(v^2/2\,g)$$

where (l/r) is the ratio between the length and the hydraulic mean depth of the pipe (using Mr. Parry's symbols in which r is the hydraulic mean depth, not the radius of the pipe). Since the kinetic head and the loss in head are both linear quantities, while the ratio (l/r) is simply a number, it follows that the factor f is likewise non-dimensional. Only a very little consideration is required to show that the factor f is simply twice as great as the "new" factor $R/\rho v^2$. As a consequence, it follows that all the advantages of the new method may be obtained by plotting f instead of $R/\rho v^2$ on a base representing $v\,.\,d/\nu$ or $\log v\,.\,d/\nu$.

The relation between the several coefficients may best be illustrated by an example, thus:

d'Arcy	$f = 0{\cdot}00644$	Applicable for any consistent set of units.
Stanton	$R/\rho v^2 = 0{\cdot}00322$	
Parry	$(R/\rho v^2) \div g = 1/C^2 = 0{\cdot}00010$	Applicable only for foot-second units.
Parry	$C^2 = 10{,}000$	
Chezy	$C = 100$	

The table shows clearly the stage at which $g = 32{\cdot}2$ ft./sec.^{2} enters the sequence, rendering the subsequent values applicable only for the foot-second system of units.

At present, civil engineers incline to use the Chezy coefficient, and mechanical engineers to use the d'Arcy factor, while few make practical use of the new factor $R/\rho v^2$, which is simply half the old d'Arcy value. In these circumstances, it seems desirable to point out that the d'Arcy factor offers all the advantages of the new method of analysis, and could be adopted as a standard with a minimum of inconvenience.

Yours very truly,

B. P. HAIGH.

Royal Naval College, Greenwich, S.E.

"THE COMMERCIAL VALUE OF KNOWLEDGE."

TO THE EDITOR OF ENGINEERING.

SIR,—On reading the replies of "Spero Meliora," Robert Keddie and "Anti-Professor" to "Graduate," in your issue of September 8, I was struck by their seeming lack of appreciation of the fundamental difficulty underlying the position of "Graduate" and many others of us. I will endeavour, therefore, to explain the point, which seems to have been missed so unaccountably by "Graduate's" critics.

Firstly, "Spero Meliora" writes of the proper course of "subjecting boys to the atmosphere and discipline of the works as soon as they leave school." Quite apart from the merits of this course for those, to whom it applies, cannot "Spero Meliora" see that the very grounds, on which we ask for special consideration, are concerned with the fact that we were not boys from school, when we entered upon our college training? Further, that on leaving school we were "subjected" to an atmosphere and discipline "far more exacting than that of the workshop." And there is the rub. The time that would normally have been spent in obtaining practical experience in the works, was spent by so many of us as our obvious duty in another field.

I would point out here that this service was every bit as much "philanthropy" as one of your correspondents describes the service which employers might render to us in return. Did we say in 1914: "We are not philanthropists. We cannot afford to run the risk of ruining our careers for a sentiment?"

Secondly, I wish to answer "Anti-Professor" who asks: "Who advised us to take the course we did?" Let him consider our position in 1919. We had left H.M. Forces nearly five years after we had left school. Where were we with regard to our intended profession? (The remarks of Mr. Keddie concerning French polishers have nothing to do with our case.) We were, most of us, less advanced than in 1914, since we had lost touch with the elementary engineering instruction we had received at school. In 1914 we were to have commenced on three years at college and two or three years in the workshop—in which order does not affect the validity of our argument—six years in all. But what of 1919? Five years of those six have already elapsed, leaving one. We must lose one or two years; that is inevitable. So we have three years at our disposal. We had to consider, and chose one of two alternatives, college or workshop—both in three years was out of the question. We chose the former, the acquisition of the knowledge so despised by "Anti-Professor." In coming to that decision we had hoped that with this knowledge to offer at the end of three years employers would give us the opportunity of gaining our practical experience. How could we have done otherwise? If with three years' technical training, a degree, and a diploma—which, after all, have some significance—we are not acceptable to employers, how would they have treated us in 1919, when we had nothing to offer?

Well, here we are in 1922; the youngest of us, as "Graduate" points out, 25. If we make a start in life now we are two years behind the normal age. If, however, we follow the normal course and spend another three years in workshops, the youngest of us will then be 28, some of us 30. Then we may make a start to earn a "living wage." The fundamental difficulty of which I spoke is, then, one of time. I am afraid no amount of consolation or advice, which ignores this fact, is of any value.

I would end, Sir, if I may be granted the hospitality of your columns, with an appeal to employers. Were the issue a clear-cut one between sentiment and business, I might yet justly appeal to the former. Actually it need not be a matter entirely of sentiment, although perhaps not strictly business. The risk is not great—ours in 1914 was greater. We have given evidence of some ability at college—in 1914 we were asked for none. My plea is for a trial, a short period of probation, and then, if our services are worth keeping, a "living wage."

I am, Sir, yours faithfully,

ANOTHER GRADUATE.

"Stanmore," Stanley Park-road, Carshalton, Surrey.
September 11, 1922.

USE OF THE GEOPHONE IN COAL MINES.—Experimental work performed by the United States Bureau of Mines at Pittsburgh, Pa., has shown that when the geophone is to be used in a coal mine to detect sounds coming through the strata, the instrument should be placed on a niche or shelf of coal rather than on the floor of the mine. Similarly the experiments conducted by the Bureau have shown that if a blow is to be struck in a mine with the purpose of being detected by the use of the geophone, the blow should be struck upon the coal.

NEW DOCK AT SUNDERLAND.—Sir William Arrol & Co., Glasgow, have secured a very considerable part of the contract for the construction of a new dry dock at Sunderland. The dock will be 500 ft. long and 75 ft. broad, and will be considerably larger than any existing dry dock on the Wear. The Glasgow firm's contract, which has been placed by Messrs. T. W. Greenwell and Co., of Sunderland, is for the construction of the dock entrance and 500 ft. of quay. This work will take about 15 months to complete. The construction of the body of the dock, which cannot be begun until part of the site has been filled in, will require another 12 months. When completed the dock will accommodate the largest vessels visiting the port.

THE JUNIOR INSTITUTION OF ENGINEERS.—This Institution, which has for many years carried on its activities for the benefit mainly of the younger members of the profession, with headquarters at 39, Victoria-street, S.W. 1, has, on account of increasing membership, been compelled to seek more accommodation; this has been found in the same building, and a suite of rooms on the first floor overlooking Victoria-street has been acquired. The suite includes adequate accommodation for the Institution staff and a reading and lecture room, with double the seating capacity of the present one. All future ordinary and Friday evening informal meetings will be held in the new home. The first meeting of the winter session will be held on Friday, October 6, when Mr. W. A. Tookey, M.I.Mech.E. (past chairman) will read a paper "Engineering in Bacon Factories." The chair will be taken at 7.30 p.m. by the president, Mr. C. H. Wordingham, supported by the president-elect, Captain H. Riall Sankey (retired), and the chairman and other officers of the Institution.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—American demand for special qualities of Cleveland pig-iron, as well as for No. 3, has created a pronounced shortage of those descriptions. Some makers have no longer any No. 3 to sell for this month's delivery, and the scarcity of No. 1 and siliceous iron is so acute that supplies are practically unobtainable. Nothing below 97*s.* 6*d.* is named for No. 1, and siliceous, whilst No. 3 is fully 90*s.*, and at least one firm of producers has this week asked as much as 95*s.* for the ruling quality. Foundry No. 4 is in ample supply at 87*s.* 6*d.*, and No. 4 forge is plentiful at 85*s.* All quotations are f.o.t. makers' works or f.o.b. Tees.

Hematite.—The East Coast hematite branch presents no new feature of moment. Values are very unsteady, but, if anything, the tendency is upwards notwithstanding the heavy stocks still held by several producers. Customers report they can purchase Nos. 1, 2 and 3 at 89*s.*, and even a trifle less, but round about 90*s.* may be given as the general market quotation, both for home consumption and for shipment abroad. Some sellers ask up to 91*s.* 6*d.* for mixed Nos.

Foreign Ore.—There is next to nothing doing in foreign ore. Consumers are well supplied and are holding off the market. They still name 24*s.* 6*d.* as the c.i.f. price of best rubio, but that figure is too high to tempt buyers. Good Mediterranean ores are 22*s.* 6*d.* to 23*s.* c.i.f. Tees.

Blast Furnace Coke.—Local consumers of Durham blast-furnace coke are very disinclined to pay the rates named by sellers. The latter, however, are in a position to take a very firm stand as they can readily dispose of their make for export. They asked 26*s.* 6*d.* to 27*s.* for average qualities delivered, but users consider the figure should not be above 26*s.*

Manufactured Iron and Steel.—Some improvement is noticeable in one or two branches of finished iron and steel. Inquiries are certainly better, and with a few orders being booked some of the extensive idle plant promises to be in motion once more in the near future; actual sales, however, are still slow. Prices are matter of individual negotiation, and home quotations vary according to destination, the cost of carriage being added in cases of long distance. Export orders can be placed at a good deal below the following figures which are named for local delivery:—Common iron bars, 11*l.*; iron angles, 11*l.*; iron ship rivets, 12*l.* 17*s.* 6*d.*; steel billets (medium), 7*l.* 5*s.*; steel billets (hard), 8*l.*; steel boiler plates, 12*l.* 10*s.*; steel ship, bridge and tank plates, 9*l.*; steel angles, 8*l.* 10*s.*; steel joists, 9*l.*; steel tees, 10*l.*; heavy sections of steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*; black sheets, 12*l.*; and galvanised corrugated sheets (24-in. gauge, in bundles), 16*l.* 10*s.*

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Trade.—In addition to the big business done with the United States, steady expansion in Continental trade is reflected in the official returns of South Yorkshire coal traffic *via* Hull. Last month Germany, the United States, North Russia and France together took over 200,000 tons, as against total exports of 56,000 tons in August, 1921. Germany was by far the largest buyer with 100,055 tons. The United States were second in the list with 67,302 tons. Shipments for January to August inclusive showed a sixfold increase compared with the corresponding period last year, the respective totals being 1,503,933 tons and 249,057 tons. The gross quantity received at Hull for the eight months advanced 2,023,000 tons in comparison with the first eight months of 1921. On the month as compared with August, 1921, the Brodsworth, Bullcroft, Hickleton, Ramcroft and Yorkshire Main group more than doubled its tonnage, despatching over 95,000 tons. Denaby and Cadeby Main were good seconds with 40,645 tons, and other principal contributors were Manvers Main 25,000 tons, Bentley 23,000 tons, Peckfield 22,000 tons, and the Carlton group 19,000 tons.

Iron and Steel.—Current developments show conclusively that prospects are brightening, but actual improvement in the general steel and engineering branches is so slow as to be almost imperceptible, and it becomes increasingly apparent that trying conditions will have to be faced during the winter. None realises this more than Sheffield's Lord Mayor (Alderman C. Simpson), who, in conjunction with the mayors of the Tyneside, continues to exert every effort to secure the early placing of orders for the two new cruisers that are to be laid down. But even if Sheffield gets a substantial share of this work in the provision of steel, machinery and shipbuilding parts, it will be insufficient to employ more than a small proportion of idle operatives, whose ranks have not been materially reduced since the last engineering trouble, and still remain round the 40,000 level. The improvement in common steels (which is steadily maintained) has proved a boon to workers in the Rotherham area. Output remains at roundly 60 per cent. of furnace capacity. Most of the orders on hand have been secured at cut prices in face of severe competition from other districts. Producers, however, are satisfied with small profits for the time being in the hope and expectation that once the buying movement gets a fair start other consumers will come forward for fear of being left in the lurch, and values will thus attain a more economic basis. Unfortunately acid and special steels, for the production of which Sheffield is mainly equipped, are much slower in recovering, though the steady absorption of stocks left over from war requirements leaves a better opening

for current output. Increased tariffs in foreign countries and the threat of still further impositions have done much to obstruct the forward movement in high-speed and other tungsten steels. Crucible furnaces are, however, more active than a month ago, and manufacturers are hoping that when the full effect of the latest bonus cuts is experienced, buyers on both home and overseas account will be induced to spend more liberally in meeting commitments long overdue. Here, as in common steels, the opinion is growing that values have reached absolute rock-bottom, and that any variation must necessarily be upwards. Shipbuilding prospects are held to have been improved by the reduction of the surplus tonnage, resulting chiefly from fuel deliveries to America. Provincial corporations are coming more readily into the market to cover delayed renewals. Points and crossings and manganese materials are on order for several provincial centres. The popularity of the most recent electric welding process in repairs to tramway track, which dispenses with the use of bolts and nuts, has spread to the Colonies. Special fishplates and clamps are on order for South Africa. Inside pressure brought to bear on home railway companies to expedite orders for rolling stock has not been without effect. Two of the largest amalgamations are reported to be in the market for tyres and rails. Electrical and textile requirements keep machinery makers busy. Motor-cycle manufacturers have ceased to supply solely from stock, but the latest buying movement will require a much greater fillip before serious inroad is made into heavy reserves of parts and fittings. Implement makers are able to show improved bookings of circular saws, mainly for shipment. Rustless iron and the new tarnish-resisting nickel alloy are proving useful auxiliaries.

South Yorkshire Coal Trade.—In best steam hards the position is still mainly dominated by the export demand. Apart from American trade, which continues to absorb a big tonnage of steams and coke, the Continent is taking increasing quantities. When, in addition, a steadily strengthening call from home industries is taken into account, collieries have no difficulty in keeping clear of stocks. There is, on the other hand, a surplus of cobbles and nuts, while slacks are somewhat easier. Conditions in the house-coal trade are irregular. For best qualities there is a ready market at increased prices, but inferior sorts are sagging. Supplies of furnace and foundry coke are on the short side. Quotations:—Best branch handpicked, 36*s.* to 37*s.*; Barnsley best Silkstone, 33*s.* to 34*s.*; Derbyshire best brights, 23*s.* to 24*s.*; Derbyshire best house, 21*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best large nuts, 19*s.* to 21*s.* 6*d.*; Derbyshire best small nuts, 15*s.* to 16*s.* 6*d.*; Yorkshire hards, 21*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire hards, 19*s.* 6*d.* to 21*s.*; rough slacks, 8*s.* 6*d.* to 10*s.* 6*d.*; nutty slacks, 7*s.* 6*d.* to 8*s.* 6*d.*; smalls, 3*s.* to 5*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

State of Trade.—The state of trade in general throughout Scotland is still very poor, and little change has taken place during recent weeks. The prosperity of the country is so largely dependent on the shipbuilding industry that little real improvement can be expected until the shipyards get busier. The conference which took place in Edinburgh on Monday of this week, between the shipbuilding employers and the representatives of the shipyard workers has been adjourned. The employers' view of the situation is that if new tonnage is to be secured the costs must come down and the men must submit to the loss of the remaining 10*s.* of the 26*s.* 6*d.* war bonus. The men's representatives debated the necessity of such a reduction, and after a long discussion it was agreed to adjourn the conference until the different unions interested had again considered the matter.

Scottish Steel Trade.—A quiet tone continues to prevail in the Scottish steel trade, and there is still a great scarcity of orders. Buyers are very slow in coming forward, and orders are small and for immediate requirements only. Producers have difficulty in securing enough to keep the plate mills which are in commission moving at all, but for structural sections there is a fair demand. Makers of black sheets are doing moderately well with the thinner gauges for export, but the home trade is very poor, while little business is being put through for the heavier qualities. The following are the current quotations:—Boiler plates, 12*l.* 10*s.* per ton; ship plates, 9*l.* per ton; sections, 8*l.* 15*s.* per ton; and sheets, 10*l.* 5*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—There has been little development in the West of Scotland malleable iron trade over the week and employment is far from satisfactory. A limited amount of business is passing on export account. Prices are unchanged, with "crown" bars at 10*l.* 10*s.* per ton, delivered Glasgow.

Scottish Pig-Iron Trade.—The demand for Scottish pig-iron for export has continued exceedingly steady during the past few weeks, and stocks have almost been exhausted. The shipments to America have been good, but although to-day's demand is not just so heavy no appreciable falling off is anticipated for a little time yet as there is a distinct scarcity of pig-iron on the other side. The home demand continues very poor, particularly for hematite iron, but there is a moderate amount of business in foundry sorts. Prices keep firm and are as follow:—Hematite, 5*l.* 7*s.* 6*d.* per ton, delivered at the steel works; foundry iron No. 1, 5*l.* 5*s.* per ton; and No. 3, 5*l.* per ton, both on trucks at makers' works. Intimation has just been made that the iron works of Messrs. Dixon on the south side of Glasgow, are about to be reopened after a long spell of idleness. Workmen are now carrying out the preparatory work for a restart of the furnaces within the next week or two.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Though inquiries for Welsh coal are fairly numerous, definite orders are few and prices generally are weaker for all grades with the exception of anthracites. The American and Canadian demand has appreciably slackened, while Continental and European buyers are holding off in the hope of eventually securing their supplies at lower figures. Best Admiralty large is now obtainable at 27*s.* 6*d.* to 28*s.*; seconds 26*s.* to 27*s.*, and the leading Monmouthshires from 25*s.* 6*d.* to 26*s.* with dry large at 27*s.* 6*d.* to 28*s.* Smalls are plentiful with prices easy on the basis of 17*s.* 6*d.* for best steam and from 12*s.* to 15*s.* for dry smalls. Heavy shipments are still being made to the United States and Canada, and many cargoes are to go. Of last week's total shipments of 596,900 tons, 213,700 tons, or 36 per cent. of the total, went to America, bringing the total shipments to date to 834,900 tons. Charterings have been reported for 1,447,300 tons, so that at least another 500,000 tons remain to be shipped to the States. Of last week's shipments 191,140 tons were despatched to the United States and 22,590 tons to Canada, while 7 more steamers to carry 36,200 tons were chartered, and 19 vessels of 58,469 net tons were "entered outwards." Mr. Evan Williams, chairman over the owners' side of the South Wales Coal Conciliation Board, at a meeting held at Cardiff yesterday, warned the men of any action which might lead to an increase in working costs. He stated that the financial position of some collieries was so exhausted that any further increase in cost would imperil the continuance of work at these collieries, and for this reason the workmen should not press their demand for any increase in the wages of the lower-paid day men. Despite this warning the workmen's representatives stated that they intended to persist in their demand of an extra 1*s.* per day for men over 21 years of age, 9*d.* for those between 18 and 21, in each case to be subject to a maximum of 7*s.* 6*d.* per day. In the event of failure to agree the matter is to go before the independent chairman of the Board. The workmen received the reply of the owners to the proposal that they should co-operate with the men on the matter of non-unionists. The owners reiterated their past policy on the grounds that the question of the membership of trade unions was one which was entirely outside their purview and concerned only the Federation. It was not one of the functions of the owners to bring pressure upon or influence a workman to join a union, neither could the owner be expected to give facilities at the collieries to enable the workmen's representatives to bring pressure to bear upon the workmen to join the Federation.

Iron and Steel.—New orders for Welsh tin plates continue to come along very slowly, but despite this prices keep fairly steady on the basis of 19*s.* to 19*s.* 3*d.* for standard boxes. Exports of iron and steel goods last week were substantially increased, the total of 16,586 tons comparing with only 2,703 tons in the previous week. Of last week's shipments 1,332 tons consisted of black plates, 9,714 tons tin plates, of which 1,338 tons went to South America, 1,914 tons galvanised sheets, including 1,085 tons for Calcutta, and 3,606 tons iron and steel, of which 1,437 tons went to the Far East from Swansea and 1,159 tons to Bombay from Newport.

LANTERN SLIDES FOR LECTURES.—The National Gas Engine Company, Limited, Ashton-under-Lyne, state they will be pleased to render all the assistance in their power during the coming winter to lecturers who wish to deal with the subject of internal-combustion engines and/or suction gas plants, by lending them free of charge a selection of lantern slides, views of their works, installations of all sizes, sectional views, &c. A descriptive list of the slides will be forwarded on request. They will also be pleased to give assistance in the preparation of lectures as far as their own manufactures are concerned.

SAFETY DEVICES ON ELECTRIC MINE LAMPS.—In view of frequent expressions of doubt as to the necessity of the use of a safety device on portable electric miners' lamps designed for use in explosive mine atmospheres which would be effective in opening the bulb circuit whenever the bulb was broken, the United States Bureau of Mines recently conducted, at the Pittsburgh, Pa., experiment station, a series of tests with bulbs such as are being used to-day on miners' lamps energised with 2-volt lead cells. The results of the tests afford the most convincing argument as to the necessity of an adequate current-interrupting safety device on miners' electric lamps. In 55 tests in which the naked filament was exposed, either at the beginning or after smashing the bulb, 51 ignitions resulted. These ignitions were all obtained with normal voltage impressed on the bulb filament. Fifteen successive ignitions on one filament showed the toughness of the filament, and how easy it is to get an explosion before the filament is burned through. The 20 smash tests in which 16 ignitions were obtained show that in the majority of cases the filament is in condition to cause ignition after the bulb glass has been broken. Though a time lag in the ignition of gaseous mixture is admitted, these tests show that the time lag of the filaments burning through is greater, and consequently can by no means be relied on as a protection against gas ignition. The Bureau of Mines feels that its policy of requiring a safety device on electric miners' lamps is both wise and necessary. The bureau recommends to the user of portable electric lamps more attention to the careful maintenance of the safety devices of such lamps, and discourages the use of any modifications that interfere with their proper operation.

NOTICE OF MEETING.

THE INSTITUTE OF METALS.—Autumn Meeting, Swansea, September 19 to 22, in the Llewellyn Hall, Y.M.C.A. Tuesday, September 19, at 8 p.m.: First Annual Lecture on "Subjects of Practical Interest to those Engaged in the Non-Ferrous Metals Industry." "The Science of Human Effort (Motion Study and Vocational Training)," by Dr. R. S. Hutton. Wednesday, Thursday and Friday, September 20 to 22, at 10 a.m.: The following papers will be read and discussed: (1) Sixth Report to the Corrosion Research Committee of the Institute of Metals on "The Nature of Corrosive Action" and the "Function of Colloids in Corrosion," by Mr. Guy D. Bengough, M.A., D.Sc., and Mr. J. M. Stuart, M.A.; (2) a report to the Aluminium Corrosion Research Sub-Committee of the Institute of Metals on "Experiments on the Oxide Method of Determining Aluminium," by Mr. J. E. Clennell, B.Sc.; (3) "Grain Size and Diffusion," by Professor J. H. Andrew, D.Sc., and Mr. Robert Higgins; (4) "The Structure of Eutectics," by Mr. F. L. Brady, M.Sc.; (5) "The Antimony-Bismuth System," by Mr. Maurice Cook, M.Sc.; (6) "Note on the Effect of Superheated Steam on Non-Ferrous Metals used in Locomotives," by Sir Henry Fowler, K.B.E.; (7) "The Constitution and Age-Hardening of Alloys of Aluminium with Copper, Magnesium and Silicon in the Solid State," by Marie L. V. Gayler, M.Sc.; (8) "The Hardness of the Brasses and Some Experiments on its Measurement by means of a Strainless Indentation," by Mr. F. W. Harris, M.Sc.; (9) "Note on the Cause of Red Stains on Silver-Plated Work," by Mr. A. Jefferson; (10) "New Forms of Apparatus for Determining the Linear Shrinkage and for Bottom-Pouring of Cast Metals and Alloys, accompanied by Data on the Shrinkage and Hardness of Cast Copper-Zinc Alloys," by Mr. F. Johnson, D.Sc., and Mr. W. Grantley Jones; (11) "Intermetallic Actions. The System Thallium-Arsenic," by Mr. Q. A. Mansuri, B.A., M.Sc.; (12) "White Metals," by Mr. A. H. Mundey, Mr. C. C. Bissett, B.A., B.Sc., B.Met., and Mr. J. Carttaud, M.C., M.Sc.; (13) "The Effects of Overheating and Melting on Aluminium," by Mr. W. Rosenhain, D.Sc., F.R.S., and Mr. J. D. Grogan, B.A.; (14) "The Cleaning of Aluminium Utensils," by Mr. R. Seligman, Ph.Nat.D., and Mr. Percy Williams, B.Sc.; (15) "The Copper-Rich Aluminium-Copper Alloys," by Mr. D. Stockdale, B.A. Visits to various works.

THE MANGAHAO POWER SCHEME, NEW ZEALAND.—H.M. Trade Commissioner at Wellington, N.Z., reports that the Public Works Tender Board, Wellington, are inviting tenders for the supply of outdoor and indoor switchgear for the Khandallah sub-station of the above scheme. The sub-station will receive power from two overhead three-phase lines at 110,000 volts, 50 cycles, delivered to two banks of single-phase transformers, each of 12,000 k.v.a. capacity, the secondary voltage being 11,000. Copies of the specification may be seen at the Department of Overseas Trade, 35, Old Queen-street, S.W. 1.

THE SPONTANEOUS COMBUSTION OF COAL.—The heating of coal is believed to be a surface phenomenon. If a ton of bituminous coal could be delivered in a single cube, each dimension of the cube would be about 2·8 ft. When coal heats, it is due to something that goes on with respect to the surface. It is, therefore, interesting to know the area of the total exposed surface in a ton of coal. If the cube, having originally an area of about 47 sq. ft., be divided until all the pieces are fine enough just to pass through a 16-mesh screen the area of exposed surface in one ton of coal would be an acre. The great increase in extent of surface is not serious until one gets below 1¼ in., or nut size. If fine coal is kept out of the pile the heating surface is relatively so small as to remove the cause of spontaneous combustion. A unit of area of this surface generates a certain amount of heat, provided it can find the necessary oxygen to combine with. The amount of heat generated depends upon the temperature of the coal. Coal stored during the hot months of summer and in heated regions is much more liable to spontaneous combustion than coal stored in colder climes and in cooler seasons of the year. For the first few days or weeks freshly broken coal surface is very much more active in the taking up of oxygen and consequent production of heat than after a few weeks or months. Spontaneous fires rarely occur after the coal surfaces have been exposed for three months. As the rate of heating increases with the temperature, it is evident that if the heat generated is not removed, the process becomes a self-aggravating one, and the rate of heat generation, instead of falling, may rise with time. The rise in temperature of a coal pile is intimately connected with a very complicated ventilating problem. Since there are no means of knowing just what the ventilation is in any given portion of a pile, there is great hesitancy in advocating ventilating schemes for coal piles, as one is as likely to make trouble as to prevent it, unless extreme and uniform ventilation is assured. There are many more factors of minor importance. One of the troubles has been that undue attention has often been given to the minor factors, such as the sulphur or the volatile-matter content of the coal, height of pile, &c., while the main factors, such as initial temperature, breakage in handling, freshness of the coal, and the screening before storage, have been overlooked or minimised. The various factors affecting the spontaneous combustion of coal have been recently discussed by Mr. O. P. Hood in Technical Paper 311, issued by the United States Bureau of Mines, Washington, D.C.

THE CANADIAN PACIFIC LINER "EMPRESS OF CANADA."

CONSTRUCTED BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., ENGINEERS AND SHIPBUILDERS, GOVAN, GLASGOW.

(*For Description, see Page* 317.)

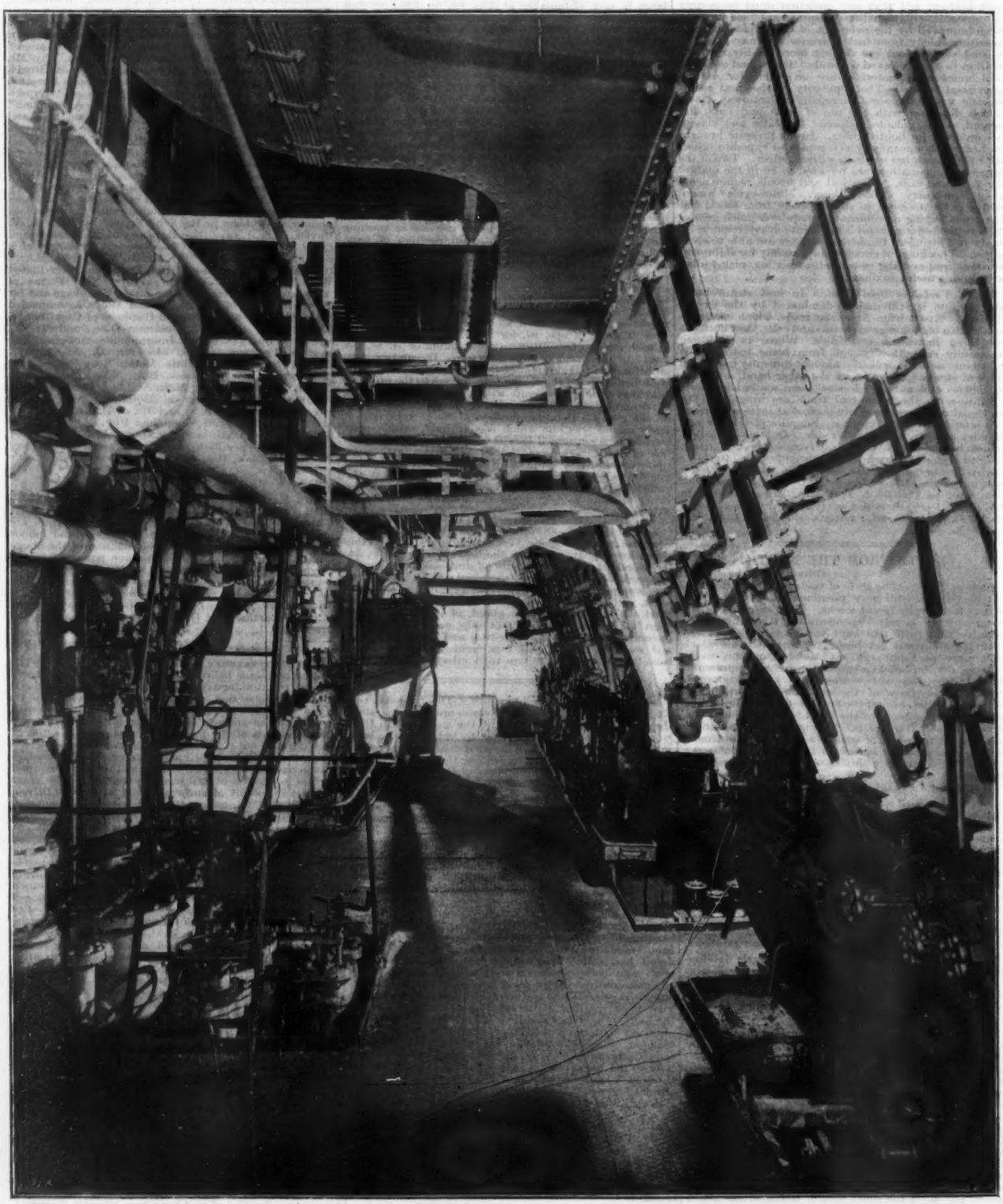


FIG. 42. VIEW OF STOKEHOLD.

THE CANADIAN PACIFIC LINER "EMPRESS OF CANADA"; ARRANGEMENT OF MACHINERY.

CONSTRUCTED BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LIMITED, ENGINEERS AND SHIPBUILDERS, GOVAN, GLASGOW.

(*For Description, see Page* 317.)

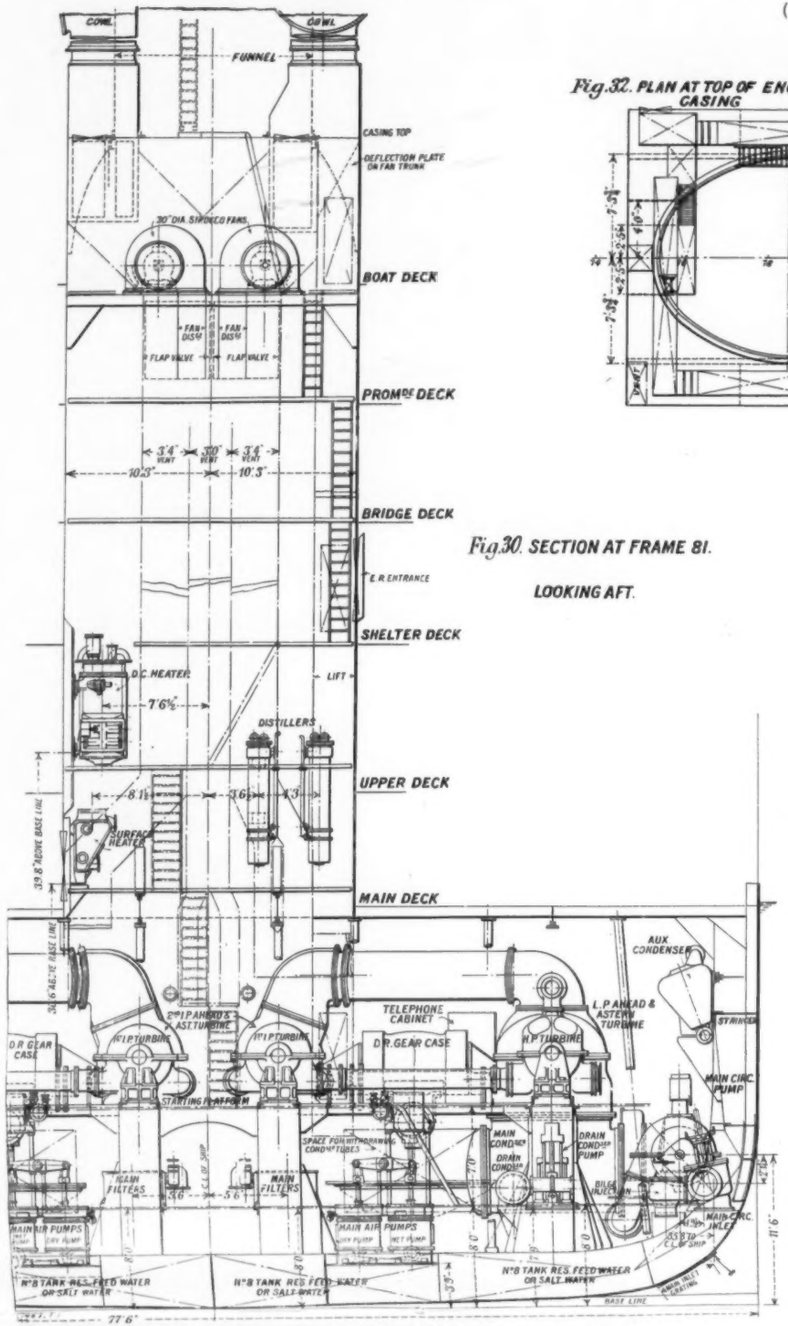


Fig.30. SECTION AT FRAME 81. LOOKING AFT.

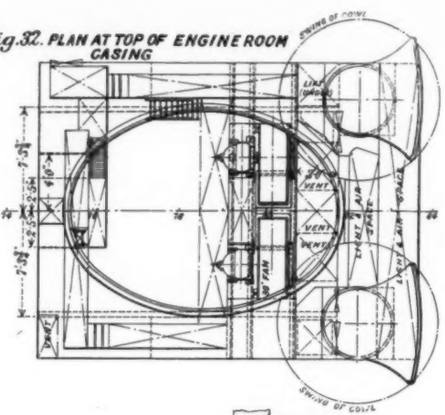


Fig.32. PLAN AT TOP OF ENGINE ROOM CASING

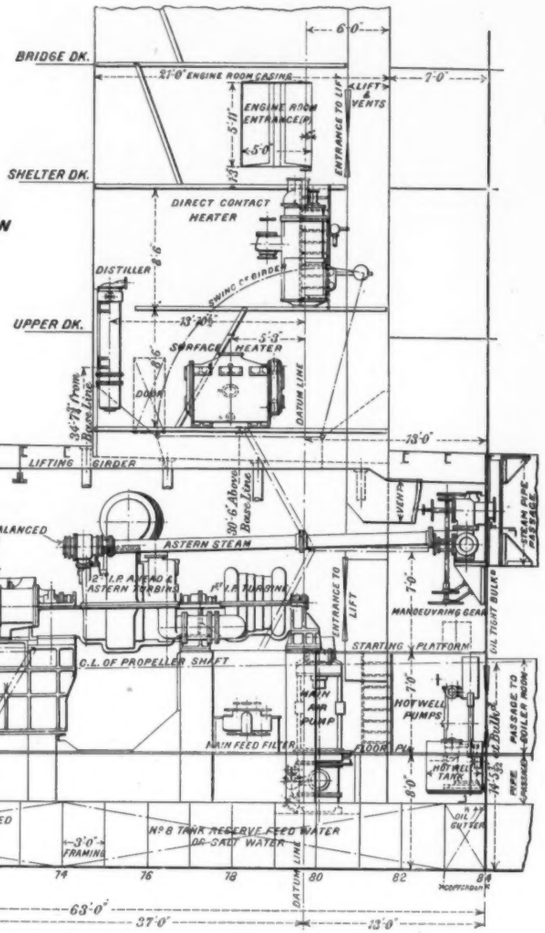


Fig.31. ELEVATION AT C.L. OF SHIP.

Fig.33. PLAN AT ORLOP DECK LEVEL

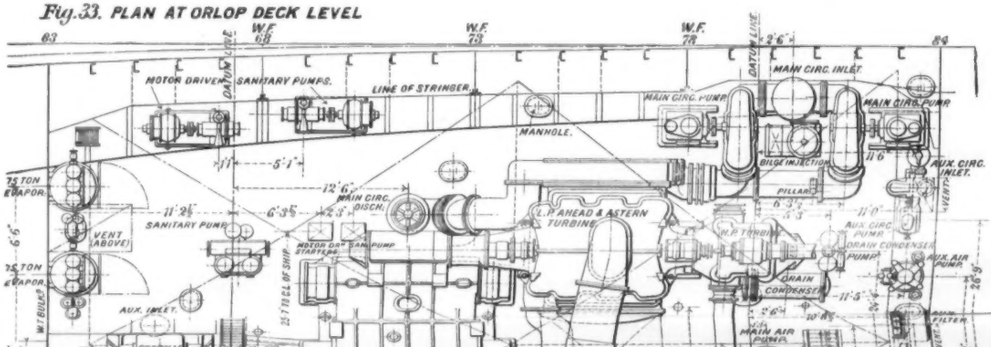


Fig. 35. SECTION AT FRAME No 81. LOOKING FORWARD.

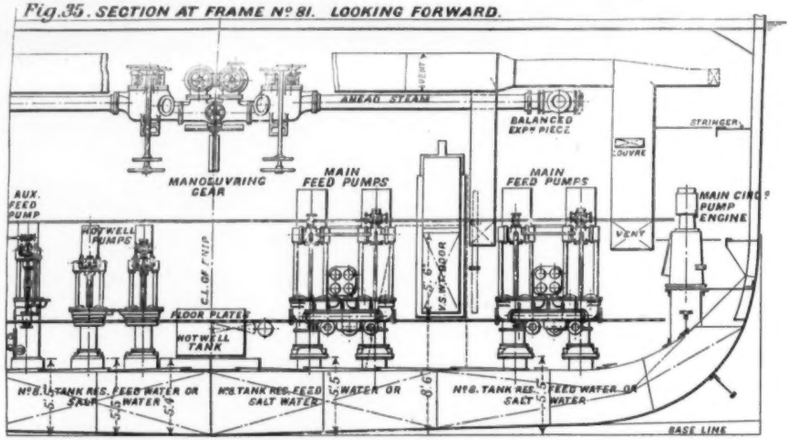


Fig. 36. SECTION AT FRAME No 68. LOOKING FORWARD.

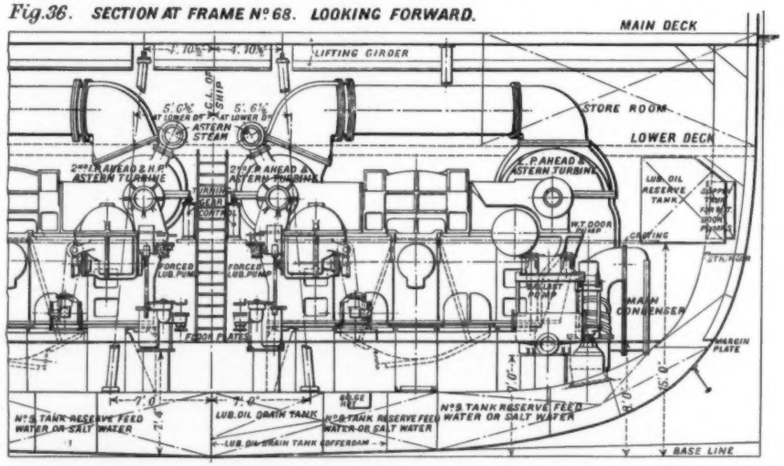
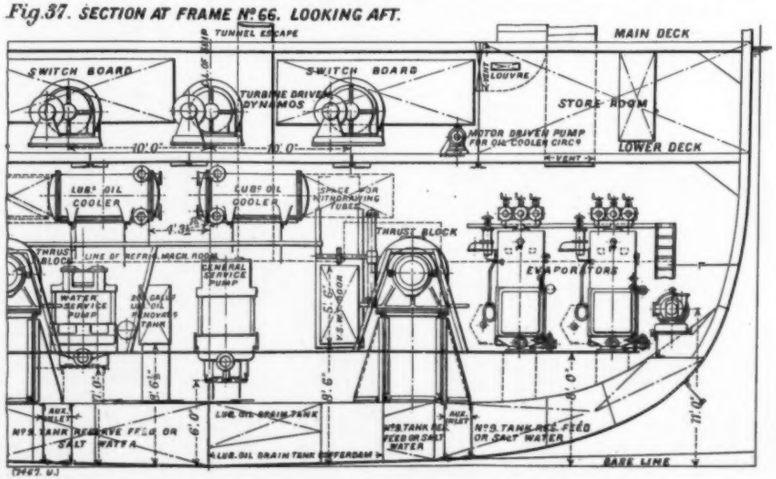


Fig. 37. SECTION AT FRAME No 66. LOOKING AFT.



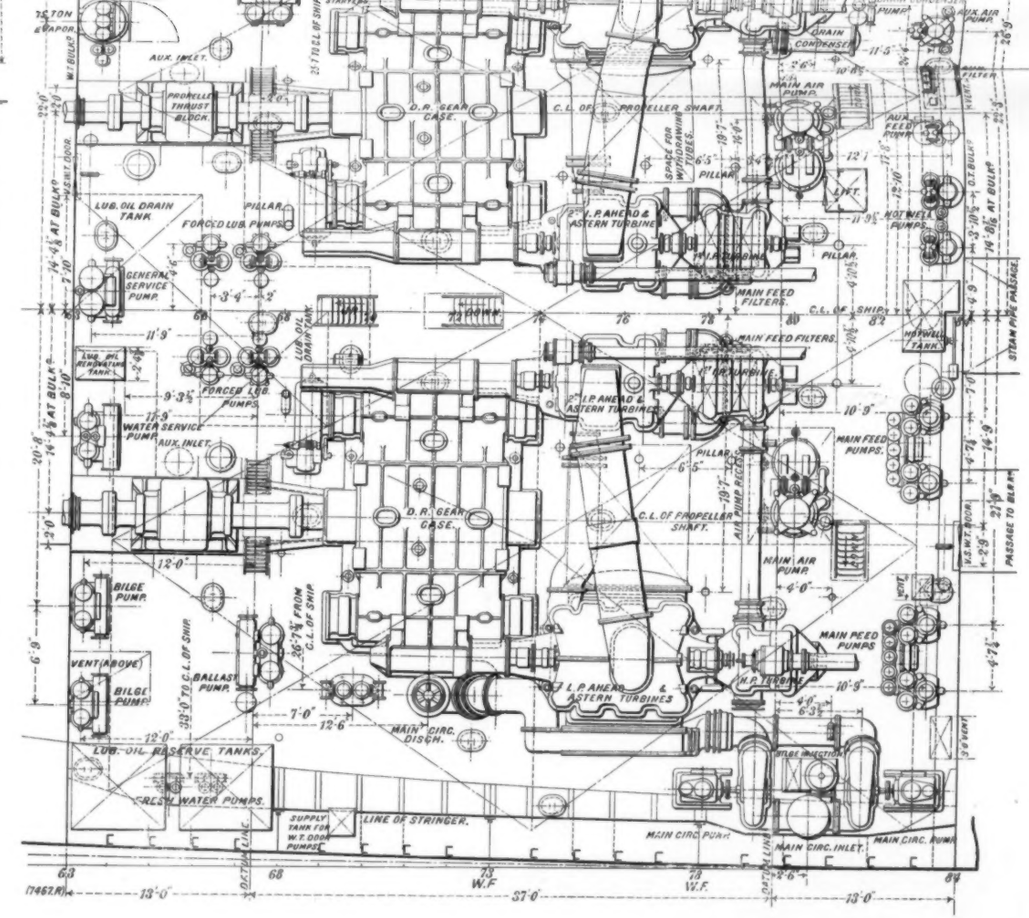
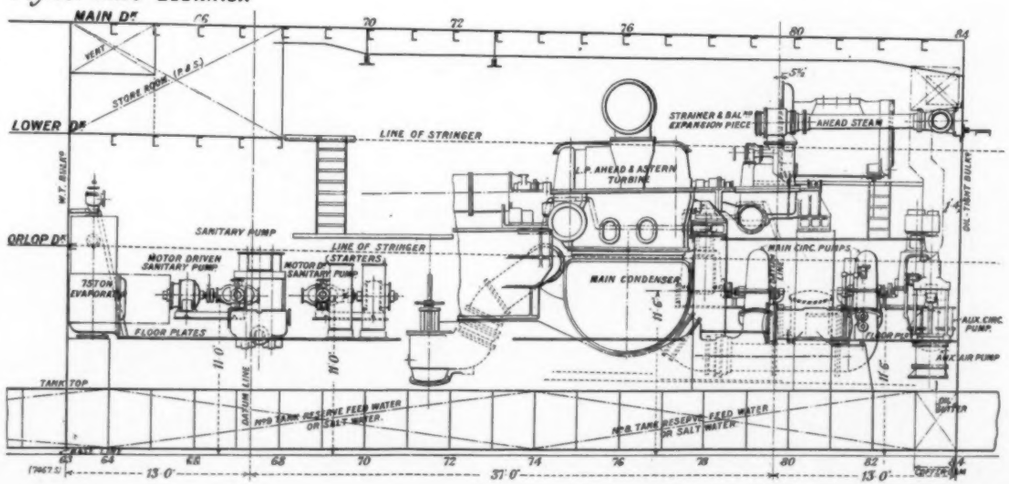


Fig. 34. WING ELEVATION



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ENGINEERING.

FRIDAY, SEPTEMBER 15, 1922.

THE MINISTRY OF TRANSPORT AND RAILWAY BRIDGES.

IT is common knowledge that a draft report on the design of railway bridges recently issued by the Ministry of Transport has given rise to much discussion amongst the engineers responsible for the safety of our railways. The meeting of the British Association at Hull has afforded an opportunity for ventilating the subject, and several very valuable and instructive papers were read and discussed. Unfortunately the traditions of our public services are, in general, opposed to the participation of officials in debates of this kind, though the prescription in question has not been observed by the Admiralty, and naval officers have accordingly made many valuable contributions to the proceedings of the Institution of Naval Architects and of the Institute of Metals. The Admiralty, however, stands on a different footing to other Government Departments, being responsible only for the well-being and conduct of the Navy, and not for regulating and controlling non-official undertakings. Nevertheless, though there may be good reasons for the rule that officials shall not take part in public discussions, it can hardly be doubted that at times the restriction acts to the disadvantage of the commonwealth, and had the Ministry of Transport had a representative at Hull it is quite possible that he might have shown that the alarm felt by many railway engineers was due to a misunderstanding.

Messrs. Cookson and Nicholas, in their exceedingly valuable paper on "The Strength of Railway Bridges," which will be found on page 293 of our last issue, take the view that the draft report calls for an enormous increase in the factors of safety now in use, and which have been proved perfectly satisfactory by long experience. It is quite certain that this is not an unnatural or illegitimate interpretation of the phrasing of the report, but it is possible nevertheless that something entirely different was really intended. Put into plain language, the draft report proposed that to express a live load stress in the terms of the static stress produced by the same load, the static stress must be multiplied by a factor which in certain cases might have a value as great as 2·59.

No rule is, however, laid down in the draft report as to how the static stress due to a specified load is to be determined, and it is a very natural assumption that these static stresses are intended to be computed by the ordinary conventional methods, while if this be true there is ample justification for the adverse criticisms of Messrs. Cookson and Nicholas. Enormous additions would be required to bridges, which an experience extending over 60 years has proved to be fully adequate to their work. It appears, however, that the method of calculating static stresses is nowhere specified in the report, and so far as the wording of this goes the engineer is at full liberty to make any allowance, sanctioned by his experience and judgment, for the fact that the actual static stresses on bridge members are always very substantially lower than those computed in the conventional way. If this be so, however, the case against the draft proposal is hardly weakened, but the basis of objection is changed. On this view the bridge engineer is trusted to use his judgment as to how he computes a static stress, but he is given no discretion as to what allowance, if any, he should make for impact. If this interpretation of the meaning of the draft rule be correct, the proposal would appear to be somewhat illogical.

As a matter of fact, indeed, it is impracticable to determine accurately the actual stresses on a bridge structure merely from the information conveyed by the drawings and specifications. In general, for example, the floor system takes part of the flange stresses. Members again are calculated as if they were free at the ends, whereas they are actually rigid, and as a consequence the deflection of a riveted bridge is always less than the calculated value. It appears, moreover, from such data as are at present available that the measured stress in individual bridge members bears much the same proportion to the calculated stress as does the calculated deflection of the structure as a whole to the observed deflection.

Whilst objection may fairly be taken in our present state of ignorance, for the imposition on engineers of an official impact factor, there can be no question as to the desirability and importance of the work now being done by the Ministry in ascertaining what the actual stresses in bridges really are. On this head our information has been exceedingly meagre. Until very recently the only accurate observations made were those carried out some 30 years ago by M. Rabut on the bridges of the Western of France Railway. He found that any strain-measurer used, required to be designed with the very greatest care, otherwise the records obtained were vitiated by inertia effects or by resonance. The instrument used by the Ministry of Transport is the Fereday-Palmer stress-recorder, which was fully described and illustrated in our issue of January 30, 1920, page 139. The moving part of this recorder weighs only some 12 grains, so that inertia errors are eliminated, whilst the natural periodicity of the instrument is about 400 cycles per second.

The records obtained with this instrument from bridges under moving loads show that the mean stress due to a rapidly moving load is some 10 per cent. greater than that due to the same load at rest or moving at, say, 1 or 2 miles per hour. Superimposed on this mean "high speed" strain are however, a number of vibrations which have a periodicity of some 30 cycles or 40 cycles per second. It is therefore very important that the natural periodicity of any extensometer adopted should be much more than this, or resonance effects may deprive the observation of all evidential value. With the Fereday instrument the natural periodicity is, it will be seen, far above the danger limit. That the vibrations superimposed on the mean curve really do represent stresses seems satisfactorily demonstrated by an experiment in which the instrument was wedged so as to prevent it recording the strains of the member to which it was attached, but leaving it free to record its own vibrations. The records thus obtained with a load moving over the bridge showed just small oscillations at the rate of 400 or so per second, with no trace of the larger oscillations already noted as super-imposed on the mean strain line.

It appears therefore that these vibrations actually do represent variations in the stress, but the point still requires clearing up as to how such rapid oscillating stresses about a mean value affect the strength of a bridge member. It will not be disputed that there is but seldom any simple and direct relationship between stress and strength. Steam boiler shells have commonly a factor of safety of 5, whilst with rifle barrels the factor of safety is about 2, and in the case of the cylinders used by Professor Bridgman in his experiments with intense hydraulic pressures the material is stressed so highly that it acquires a large permanent set. In each instance, however, in spite of the great difference in the working stresses an ample margin of safety is secured. We cannot say *a priori* how the vibrational stresses observed with the Fereday recorder affect the safety of a bridge structure. It is common knowledge that a bar can withstand with safety a momentary stress far in excess of its strength under static test, and thus there may be a time factor involved in the interpretation of the strain records. Some laboratory experiments have been made in which the repetitions of stress had about the same periodicity as the vibrations observed in the records obtained by the Ministry of Transport. In most cases, however, the experiments have been made with rotating bars, of which the endurance under these rapid alternations proved to be about the same as at lower rates of repetition.

The circumstance that in rotating bar tests the stress is reversed is a very material factor, as it is generally agreed that a stress reversal is more serious than a variation of stress without change of sign. Some pulsating tests made at about the same speed are described in the paper by Mr. Wilson and Professor Haigh, and they conclude that fatigue cannot occur within the yield range. Apparently, however, the endurance was no greater than at lower rates of pulsation, an observation which suggests that the vibrations recorded in the strain diagrams obtained from bridge members are not sufficiently rapid for the time factor to be of importance.

What appears to be a fatal defect in all formulas for impact so far proposed is that the factor is made to depend solely on the length of the span, and not at all on the character of the bridge structure. On the other hand maintenance engineers seem agreed that any impact effect is much less serious with a heavy ballasted floor than with a light open one. If an impact allowance is merely a matter of length of span this circumstance should be reflected on the experience of maintenance engineers, but Messrs. Cookson and Nicholas state that excellent results have been obtained with 12 ft. spans constructed simply of Barlow rails laid side by side in which the computed stress is over 9 tons per square inch, and is perhaps actually more.

Whilst, as already pointed out, the accurate computation of stresses in a new bridge is at least commercially impossible, it should be feasible to account approximately for the discrepancy between the observed and the calculated stress in any particular bridge member. This is a much more restricted problem than that of computing *ab initio* the actual stresses in all members, taking into account the rigidity of their connections and the assistance rendered to the flanges by the roadway and other cross bracing. Messrs. Cookson and Nicholas draw attention to a remarkable discrepancy between the stresses observed in an old riveted cross girder and those computed in the usual way.

It would seem, however, that at least part of the discrepancy found in this particular case is due to the method of calculation adopted, which is that generally given in the textbooks. Apparently the girder in question is a symmetrical one, but the neutral axis has not been taken at mid height. This involves the assumption that the strains at the top and bottom flanges are different, and some support is afforded to this hypothesis by one of the many interesting experiments described in the paper by Mr. J. S. Wilson and Professor B. P. Haigh, which we printed on page 309 of our last issue. These observers measured the stretch of a plate perforated with rivet holes as compared with that of a solid plate carrying the same total load. They found that the apparent elastic modulus was lower for the perforated bar, but was not reduced in proportion to the net area. In this experiment the holes were unfilled, whilst those in the flange of a riveted girder are filled by rivets and are apparently actually subjected to some considerable pressure along their circumferences, since the authors observe that when rivets are put into long members there is commonly a slight increase in the length. With holes thus filled the stretch modulus may well be sensibly the same for the top and bottom flanges of a riveted girder, and in this case for a symmetrical type the neutral axis will be at mid-height. It is also conceivable that friction at the supports was not negligible in the experiments described by Messrs. Cookson and Nicholas, and allowance for this would, we imagine, still further reduce the discrepancy between observation and calculation.

In Mr. Gribble's paper, which was printed on page 307 of our last issue, the vexed question of secondary stresses is discussed. The term secondary stress is perhaps less definite than is desirable. A term less liable to misinterpretation would be indeterminate stresses, such as arise from the rigidity of the joints of a bridge or from the adoption of double intersection trusses. If thus restricted there can be little doubt that so long as no reversal takes place, these secondary stresses are of no practical importance, whatever their nominal value. If at any point the strain becomes excessive, the metal merely takes a slight permanent stretch and thus passes on its overload to its neighbours which must previously have been taking less than their fair share.

If, however, we use the term secondary stress to describe such stresses as may be set up in the latticing of built-up compression members by accidental flexure, then such stresses are by no means unimportant, as disastrous experience has shown.

Taken on the whole, bridgework in general is very lightly strained. According to an estimate published by the American Research Council, main bridge members are only subjected during their life to about 2,000,000 repetitions of stress, whilst the shaft of a steam turbine may be called on to sustain 15,000,000,000 variations of stress during its lifetime and a car axle 360,000,000. In the latter case the stresses are, moreover, completely reversed at each revolution. If our memory serves us, Sir Benjamin Baker estimated the maximum stress in the Conway and Menai tubular bridges at something like 13,000 lb. per square inch, the material being iron, but he felt nevertheless completely assured of their safety. Early engineers thought more and calculated less than many of their modern representatives, and these bridges were designed in a very scientific way, viz., by the test of models to destruction. This procedure has been denounced by theorists, because in such tests the elastic limit is necessarily exceeded, and in their theories this limit looms large. It is nevertheless interesting to note that in the investigations on fatigue carried out at the engineering experiment station of the University of Illinois the engineers in charge concluded that the ultimate strength of a material was a better index of its endurance than was the elastic limit.

This observation adds importance to Mr. Gribble's proposal that certain of the bridges yearly removed from service by our railway companies should be tested to destruction. A simple and cheap plan of doing this would be to lay a pair of girders alongside each other on level ground, with their top flanges adjacent. If the extremities were then connected by suitable links, loads could be applied by hydraulic jacks placed between the adjacent flanges. Even if carried out somewhat crudely valuable data should be secured. The total load applied could be determined simply and sufficiently accurately by fixing stress recorders on the links coupling together the ends of the two girders. Of course in such a test the girders would not be assisted, as they are in practice by the help they receive from the floor, which in certain cases at any rate, carries no inconsiderable fraction of the calculated flange stresses. This being so it would certainly be also well worth while, as Mr. Gribble suggests, to test to destruction the bridge complete in all its details.

That we have yet much to learn as to the endurance of metals under pulsating stresses is clearly indicated by a novel experiment described in the paper by Mr. J. S. Wilson and Professor Haigh. As is well known, if a bar is to be tested under such stresses, it has been found very essential that the fillets between the body of a specimen and its shoulders should be of very large radius, otherwise failure will occur there instead of in the body of the specimen. Arguing from analogy, it might be anticipated that equally serious effects would arise on perforating a specimen with a small hole, but on trying the experiment, the authors in question found that the endurance of the specimen was practically the same as that of an unperforated bar. It would be interesting to repeat the experiment with alternating stresses.

AUSTRALIAN RAILWAY PROBLEMS.

In his presidential address delivered before Section G of the British Association on Friday last, Professor T. Hudson Beare excused himself for the choice of part of his subject on the ground that the question he dealt with would involve an expenditure of anything up to 100,000,000*l.* on engineering work. This large sum was referred to by Professor Beare, in connection with the unification of the gauges of the Australian railways. Further expenditure would be involved to the tune of something like 15,000,000*l.* on the second subject to which Professor Beare drew attention, to wit, the construction of the North-South Transcontinental line so long discussed.

In these matters Australia is in an unfortunate predicament. Originally, when unification was talked about the cost of conversion, though comparatively moderate, was altogether out of proportion to the then financial capabilities of the States, and as there was no central body to foster and further the movement, and little prospect of agreement as to the allocation of the cost, nothing was done. Latterly, as our readers are aware, greater progress has been made. A standard has been decided upon for the gauge; but there appears to be little hope even now of raising the required money. The cost is much higher than formerly, and will increase continually, since, pending definite action in the direction of unification, the States continue to construct new lines to their several respective gauges. The apportionment of costs so far as we know has not yet been definitely decided, and this now appears to us one of the main points to settle. Unfortunately Professor Beare does not throw any light on this issue, but it appears to us it is hardly just—as the benefit of unification will be felt by all—to say Victoria and West Australia should be mulcted in heavy costs for reconstruction, and New South Wales escape practically free, because the standard adopted has been 4 ft. 8½ in. instead of 3 ft. 6 in. or 5 ft. 3 in. The matter is, now that the verdict has been given definitely in favour of one gauge, one of financial rather than engineering problems. The urgency of the matter from some points of view might be taken as evident. The inconvenience to passenger traffic, though irritating, is trifling compared with the losses entailed in the present system of transhipment in connection with freight. Some figures for Albury, the main line interchange point for traffic between Victoria and New South Wales, will make this clear. At this point the ordinary freight transhipped in a day averages about 1,000 tons, while on occasions 1,800 tons of coal crosses the border in a day and over 10,000 head of stock, to say nothing of perishable fruit traffic and so on. While these are not quantities for which handling arrangements cannot easily be organised, the point is that all that is so involved is waste labour and entails loss of time to goods and trucks. On the other hand, if unification were definitely faced, and if such large sums are involved, would the direct savings and indirect advantages more than cover the cost of raising the necessary money?

There are, as is well known, proposals for a modified scheme which would merely provide a trunk line of uniform gauge from Perth to Brisbane. As far as we can see, however, such a scheme would not result in material improvement.

It would abolish the barriers between the states, but it would transfer transhipment difficulties to a still larger number of points within the several states, where, in Queensland, Victoria, South and West Australia, other gauges came in contact with the 4 ft. 8½ in. trunk line. Transit free from transhipment would therefore in a vast number of cases be no more possible with such a scheme than at present. Possibly the inconvenience would be greater. For this reason the modified scheme is not favoured, while the expenditure for complete unification is regarded as prohibitive by many who would rather see the money expended on works which would be more quickly reproductive.

Among the latter we may, it seems, put Professor Beare, who of the alternatives of unification, or the construction of the North-South railway, favours the latter as the more promising for the country in present circumstances. Unfortunately, here also a controversy has arisen which is proving very difficult to settle. The Act under which the Commonwealth took over the Northern Territory from South Australia, stipulates the construction of a line to connect Port Darwin with a point on the northern boundary of South Australia, and also a line from a point on the Port Augusta-Oodnadatta railway to the same border, to connect with the northern section. South Australia stands by the letter of the law, as the state is anxious to open up by means of railway communication a large part of the interior hitherto almost inaccessible. However, an attractive alternative, which has many advocates, has been proposed. In this scheme the line would branch off from the Oodnadatta railway and sweep to the east through Queensland, with connection with the New South Wales system as well, and then turning gradually westward would enter the Northern territory comparatively far to the North and cross over to Katherine and Port Darwin. The relative advantages of these routes have been discussed for some time, and though the country has been traversed by various official parties, decision seems to approach no nearer. More recently, Professor Beare tells us, another route has been proposed, further west for a good part of the distance than the direct north and south route, and primarily interesting of course to South Australia. Of the three routes Professor Beare has a preference for that which would traverse part of Queensland. This certainly appears the more attractive as regards interchange of traffic, &c., but it must be admitted would not give South Australia the facilities for further development quite in the direction that state anticipated at the time of the transfer of the Northern Territory to the Commonwealth, and in justice some consideration is due to this feature of the case.

NOTES.

Problems in Marine Engineering.

Accustomed as we have become to the prodigious speeds attained by war vessels, some surprise will no doubt be occasioned by Sir George Goodwin's statement that when he entered the Navy the slowest steamships in existence were the men-of-war. In his presidential address to the Institute of Marine Engineers, which was delivered on Tuesday evening last, he confessed to a number of unauthorised races between these early war vessels and mercantile steamers, in which the Navy got hopelessly beaten, although the merchantmen were not of an aristocratic class. This condition of affairs was, of course, but a temporary interlude, due to the change-over from sail to steam. In Napoleonic times, the warship appears to have been much faster than the mercantile vessel, and to-day the Navy leads very distinctly in the matter of speed. During his forty years service Admiral Goodwin saw the horizontal engine replaced by the vertical, and the boiler pressure rise from a few pounds above the atmosphere to the present limits. Forced draught was another innovation during this period, as has also been the replacement of the tank boiler by the water-tube type, and of reciprocating engines by the turbine. In view of recent debates on gear troubles it is interesting to have Sir George's view that these will be transient, and his testimony to the success of the system in the Navy. He suggested that a better understanding of metallurgy by the engineer might hasten matters, as where fractures have occurred, although the engineer may have suspected that the quality of the metal was at fault he has seldom been able to prove his case. Probably steel makers themselves would benefit if superintending engineers followed Sir George's advice in this matter. Whilst some failures no doubt have occurred owing to bad steel, in other cases it would seem that it is the engineer who has been at fault, although the steel maker was blamed. Sir George did not appear unduly sanguine as to the future of the electric drive, as he stated that it was more expensive in first cost and involved greater weights. In naval service, however, the system is claimed to have great advantages, being very economical at the low speeds at which most warship cruising is done. If the system does make its way, seagoing engineers will have, as Sir George pointed out, to devote some attention to electrical engineering. The prospects of the internal combustion engine were also discussed by Sir George, who emphasised the importance of profiting by the experience and observations of the engineer in charge. In this connection, however, one difficulty is frequently encountered, viz., that the seagoing engineer will not confine himself to describing what he has actually observed, but is inclined to colour his observations by self-formed theories, so that it is often impossible for the designer of the engines to find out what actually did occur. In the earlier portion of his address Admiral Goodwin drew attention to the immense social and economic improvements effected during his time and contrasted the clean, roomy, well-warmed and ventilated workshops of to-day with the corresponding shops of forty or fifty years ago.

Coke-Cooling in the Dry and Utilisation of the Coke Heat.

When hot coke is quenched with water after leaving the coke oven, the coke is not improved by retaining something like 5 per cent. of water which only increases its weight, and the heat of the coke is wasted. Yet every ton of hot coke might, by utilising its heat, yield something like 40 h.p. hours, and with an annual production, in this country, of more than 20,000,000 tons of coke, that waste is worth consideration. The power figures are uncertain. The specific heat of hot coke is not accurately known; but the specific heat of coke seems to increase with rising temperature, as it does in the cases of diamond and graphite. Experimenting at the Federal Fuel Testing Station at Zürich, Dr. P. Schläpfer finds that the mean specific heat of a coke with 10·5 per cent. of ashes, rose from 0·214 for the range 18 deg. to 100 deg. C., to 0·305 for the range 18 deg. to 577 deg. C., and to 0·333 for the range 18 deg. to 800 deg. C. A further rise of the mean specific heat seems probable, and coke is frequently discharged from the retort at 1,000 deg. C. From such considerations the dry coke-quenching plants of Messrs. Sulzer Brothers deserve attention. They put up the first experimental plant in the Zürich municipal gas works at Schlieren, in 1919; the plant has been working satisfactorily since, and some big plants are in the course of erection, as we see from a paper by Dr. Schläpfer in *Stahl und Eisen*, of August 17. Sulzer Brothers charge the coke into a vertical chamber or pit so arranged next to the vertical tubes of a boiler that the hot gases can be kept in circulation through the coke and the tubes, until the coke has cooled and is discharged at the bottom of the pit. As the whole chamber is otherwise kept sealed, the same gases should remain in circulation apart from the fresh air, which finds access during the charging and discharging, and from the chemical reactions. The original air present will oxidise a certain amount of the coke forming carbon dioxide which, reacting with more hot coke, will be reduced to carbon monoxide. During trial runs which the Swiss Association of Boiler Owners conducted in December, 1920, the percentage of oxygen in the chamber air varied between zero and 3·6, the percentage of CO_2 between 11 and 16, and that of CO between 1 and 15·4, while the gas temperature varied between 260 deg. and 750 deg. C. (500 deg. to 1,470 deg. F.) within the 3 hours of a cooling period. The claim of Messrs. Sulzer that the ton of hot coke would yield from 300 kg. to 400 kg. (up to nearly 900 lb.) of saturated steam was fully substantiated, although the experimental plant was by no means perfect. For one thing the coke should, if possible, drop from the coke oven directly into the pit; at Schlieren it had to be transported by trucks and finally raised again to the mouth of the pit. The capacity of the Schlieren coke-oven plant is only 20 tons per day; one of the plants now under construction will be able to deal with 150 tons of coke daily, another with 1,000 tons. There are, of course, difficulties. Friction between the hot coke and the walls of the pit, down which the coke glides, should be minimised, in order to prevent crumbling of the coke and to spare the walls of the pit for the construction of which a strong refractory material has to be adopted, and the heating surfaces of the boiler and superheater should be well proportioned. The difficulties will be more easily met in new coke-oven plants and new gas works than in old plants in which the additions have to be adapted to existing conditions. We may mention that a monograph on the subject has recently been written by L. Litinsky and published by Spamer, of Leipzig; the title is: "Trockere Kokskühlung mit Verwertung der Koksglut."

The Royal Institute of Netherland Engineers.

On the 8th inst., the Koninklijk Instituut van Ingenieurs celebrated the 75th anniversary of its foundation at The Hague. The meetings were attended by delegates from a number of leading engineering associations in Great Britain, the United States, France, Belgium, Switzerland, Germany and Austria. H.M. the Queen of the Netherlands was represented by Jonkheer Six, and the Government representatives were the Ministers of Public Works, of Industry and of Labour. The president, Mr. S. G. Everts, formerly professor of hydraulic engineering at Delft University, delivered an address at the opening meeting and welcomed the foreign guests. He pointed out that the Institute, from 180 members in 1847 had grown to a membership of 2,600 in the present year. A fifth of these members have their engineering activities in the Dutch East Indies, where they form a flourishing section of the mother society and have by-laws of their own. On the occasion of the gathering at the Hague, the Institute conferred honorary membership upon seven Netherland and 10 foreign engineers, the latter being Mr. Laubeuf, president of the Société des Ingénieurs Civils de France; Mr. G. Trasenster, president of the Liége Association of Engineers; the Hon. Sir Charles A. Parsons, past-president of the North-East Coast Institution of Engineers and Shipbuilders; Dr. J. H. Tudsberry, hon. secretary of the Institution of Civil Engineers; Mr. Ch. Le Maistre, secretary of the British Engineering Standards Association; Mr. Ch. Warren Hunt, hon. secretary of the American Society of Civil Engineers; Mr. Calvin W. Rice, secretary of the American Society of Mechanical Engineers; Dr. Ing. de Thierry, professor at Charlottenburg Technical High School; Dr. Ing. T. Rehbock, professor at the Karlsruhe Technical High School; and Dr. Ing. F. von Emperger, specialist in reinforced concrete, Vienna. A paper illustrated by lantern slides was read by Mr. R. A. van Sandick, secretary of the Institute for the last 24½ years, giving the history of this Association. A number of other papers were then read. Among these was a communication by Mr. E. Middelberg, dealing with the mud and water eruption of the Kloet volcano in Java, and with an undertaking of a novel kind which consists in driving a tunnel nearly a mile in length through the face of the mountain in order to tap the overflow from the volcano and thus avoid the risk of further disastrous eruptions such as periodically took place in the past, the last one having been in 1919 when villages were carried away and 5,000 lives were lost. In the course of the proceedings, the new home of the Institute at the Hague, 23, Prinsessegracht, was inaugurated. Following this a banquet was held, when, on behalf of the British delegates—Mr. P. V. Hunter, Institution of Electrical Engineers; Mr. Fraser Smith, North-East Coast Institution of Engineers and Shipbuilders; Mr. C. Le Maistre, British Engineering Standards Association; Mr. R. W. Dana, Institution of Naval Architects—the latter conveyed their thanks for the cordial reception accorded them, and read a message from

the Duke of Northumberland stating that the British Institution or Naval Architects were very glad to have this opportunity of expressing, through their secretary, their goodwill towards their sister society in Holland, and of congratulating them on attaining the 75th anniversary of their foundation. The services of the Dutch society towards the science of engineering were justly celebrated throughout the world, and their recent achievements in the field of shipbuilding and marine engineering had raised the sincere admiration of their British colleagues.

THE BRITISH ASSOCIATION.

SECTION G.—ENGINEERING.

(*Continued from page* 305.)

THE STRENGTH OF RAILWAY BRIDGES.

THE proceedings of the engineering section, which met in the crush room of the City Hall, commenced on Thursday morning, the 7th instant, under the chairmanship of Professor T. Hudson Beare. The vice-chairmen were Professor A. H. Gibson and Professor Sir J. B. Henderson, while Professor G. W. O. Howe again acted as recorder to the section.

The first morning was devoted to a discussion on the strength of railway bridges, the subject being introduced by a brief statement by Mr. J. S. Wilson, who dealt mainly with the case of the Torksey Bridge. Mr. Wilson's introductory remarks are reproduced in full on page 350 of this issue.

The chairman then called upon Mr. A. G. Cookson to read a communication by himself and Mr. J. S. Nicholas on the strength of railway bridges with special reference to the proposals of the Ministry of Transport. This communication we reprinted on page 293 of our last issue, so that we need not refer further to it here. At the conclusion of Mr. Cookson's paper the chairman mentioned that there were two other communications on allied subjects, and that when these had been read by their authors the three would be discussed together.

The second communication was by Mr. Conrad Gribble entitled "Present Day Problems and Tendencies in Railway Bridge Design," and this we reprint on page 307 of this issue. Before reading it the author explained that he had had but short notice to prepare his paper, the title of which appeared to cover a very wide field. Actually, he had only set out briefly one or two of the principal difficulties which confronted engineers of the day, and he expressed the hope that the paper would not be thought to be a comprehensive study of modern problems and tendencies in bridge design.

The third paper, by Mr. J. S. Wilson and Professor B. P. Haigh, dealt with the influence of rivet holes on the strength and endurance of steel structures, and discussed the arbitrary allowances made for this in relation to the results of a number of fatigue tests carried out by the authors in the Haigh electro-magnetic testing machine. The paper will be found printed in full on page 309 of our last issue.

The first speaker in the discussion was Mr. C. A. Gardner, of the Great Central Railway, who remarked that the paper which appealed most to him was that by Messrs. Cookson and Nicholas, whose conclusions were in accordance with his own. When engaged in bridge design work he had regarded it as an exact science, but he had been forced to alter his view since he had been transferred to bridge maintenance. He now thought there was a tendency to over-theorise in bridge design. With regard to the question of impact, he thought the word was a mistaken one, and he went on to point out that it was possible to skate over thin ice which would not support the weight of a stationary man. In bridge work, he said, the report of the Ministry of Transport pointed to an entirely different conclusion. Calculations in engineering matters he added were mainly aids to judgment, and allowances had to be made in most cases to give additional reserves of strength. With regard to the safety of old bridges, the speaker pointed out that such matters as the fixity of the ends of girders, the oushioning effect of sleepers and ballast and also the beam strength of the rails themselves had to be considered. These factors, he remarked, might account for the conflict between the theoretical conclusions to be derived from the Ministry of Transport report and the known reserve of strength of many old bridges which still carried loads far in excess of those for which they were originally designed.

Mr. R. Pawley, the next speaker, said the old bridge engineers were wise in making considerable allowance for corrosion, inefficient workmanship and increase in rolling loads, and remarked that one of the difficulties, from the maintenance engineers' point of view, was that plates were frequently covered up in various ways, whereas it was important to make all parts readily accessible for painting and inspection. The speaker also remarked that the combinations of railway companies now coming into being might well carry out elaborate experiments on the subject of bridge loading as they would be able to do this more easily than a single concern could. With regard to impact allowances, the speaker remarked that railway engineers were in favour of the adoption of the Pencoyd formula until something better was available.

Professor F. C. Lea, who followed, said he agreed with Messrs. Cookson and Nicholas in many respects, but was inclined to think that the practical man placed more reliance on his calculations than the really theoretical man. The speaker thought that the suggestion in the paper that the $\frac{I}{Y}$ formula did not apply, was a very dangerous one, and remarked that the more uncertainties were eliminated, the closer was the agreement between the fundamental formulæ and practical results. He thought more direct attention should be given to ascertain the exact conditions which were applying in any given case, and that before criticising the $\frac{I}{Y}$ formula the assumptions made in determining bending moments and shearing forces should be examined with greatest care. He also suggested that consideration should be given to the possibility of synchronism between the wheel loads and the natural period of vibration of the structure. This feature, he thought, might possibly explain the very high impact factors given in Major Mount's report. The loading of ballast, the speaker continued, also affected the question of impact stresses, and he mentioned the case of a bridge which had given considerable trouble from noise when unballasted, but had been completely cured of the trouble by adding ballast and sand. In a case of this kind, he said, the additional loading would alter the natural period of vibration of the structure, and would thus probably diminish the maximum stresses produced. The distribution of the sleepers, rails and cross girders was also an important matter in connection with impact. In conclusion, the speaker suggested that the problem should be attacked experimentally first by static loading of built-up girders and having determined the effect of building-up on stress distribution with static loads, the same girders should be examined with the simplest possible rolling load. In this way an endeavour should be made to determine the relationship between static and dynamic loading, and we should then be in a better position to deal with more complicated cases.

The discussion was continued by Mr. C. E. Stromeyer, who remarked that it appeared to be rather inconsistent to apply the new regulations only to new bridges. If they were correct they should apply equally to old bridges, and if not, it was unnecessary to inflict them on new structures. The speaker then referred to work carried out with his own form of strain indicator, which he said had been described in ENGINEERING in 1880, vol. xxx, page 337. Amongst the applications mentioned, he said that he had been able with this instrument to determine the position of the line of thrust in the arches for Blackfriars Bridge. He had also measured the stresses in ships' hulls during the operations of launching and drydocking and had given the results in papers read before the Institution of Naval Architects. He was not very familiar with the design of the Fereday-Palmer strain indicator, used in the Ministry of Transport experiments, but was inclined to think that in impact tests the results obtained might be exaggerated by the effects of the levers. He also suggested that it would be useful to load old bridges to destruction, and added that he had recently tested to destruction two iron boilers which were nearly 60 years old. He saw no reason why iron should deteriorate by age, and thought that any effects due to punching holes, &c., would disappear after about six months. One of the boilers referred to, he said, had burst with a plate stress of 8 tons per square inch, whereas he had expected it to withstand a breaking stress of about twice that figure. The failure, however, was explained by the existence of old cracks in the plates, and tests on specimens afterwards cut from the shell had given tenacities ranging from 17 tons to 22 tons per square inch. In conclusion, the speaker remarked that the material for modern structures was now carefully tested, and we were therefore justified in using lower factors of safety than were employed in old structures.

The next speaker, Professor Robertson, of Bristol University, said he was not acquainted with the exact form of instrument used in the Ministry of Transport tests, but he gathered that it was attached to the side of a member for the purpose of measuring the change in length. In that case, he thought the results were liable to be misleading owing to the lack of uniformity in the distribution of the stress. Professor Haigh, he said, had made some experiments with the Stromeyer gauge, and had got more consistent results when the connections were made deep in the metal than when the instrument was merely attached to the face of the test piece. The subject of stress concentration, the speaker continued, was exciting considerable interest at the present time, but the only way of showing its effect was by means of fatigue tests. With regard to secondary stresses, the object of considering them was to enable the factor of safety, or factor of ignorance, to be reduced, which could be done if the stresses were accurately known. Time, the speaker said in conclusion, did not permit him to dwell on the points raised in the paper by Mr. Wilson and Professor Haigh, but in referring briefly to the case of the specimen (I. 2), which cracked near the fillet, as shown in Fig. 9 of the paper, he remarked that this particular phenomenon justified the use of ductile material for structural work. Any part of a structure made of ductile material, if overstrained, would adjust itself to the loading of the surrounding material.

Professor Sir J. B. Henderson then spoke on the subject of resonance, remarking that the deflection of a structure for dynamic loading was twice as great as for static loading, and adding that the former could only be exceeded when resonance occurred. He referred to the case of a simple pendulum, the support of which was oscillated laterally through a distance a. In that case, he said, a_f the amplitude of the freed oscillation, was equal to

$$\frac{T a^2}{T_p^2 - T_f^2}$$

where T_a was the period of a simple pendulum of length a, T_p the natural period of the pendulum under consideration and T_f, the period of the forced oscillation. From the formula it could be seen that the amplitude might be very great when resonance occurred.

The time available for discussion having then practically elapsed, the chairman called upon the authors of the papers to reply to any of the points raised by the speakers. Mr. Nicholas, who then replied rather hurriedly, said they had been told to look carefully at old bridges, and having done so, had found a large reserve of strength. The report, however, said that they must take no account of this reserve of strength, which seemed illogical to him. There was a tendency to add to the strength of a structure and still keep the same factor of safety, whereas he thought that they would be justified in reducing this. A halt, he said, should be called in the matter of increasing weight, and he added that bridge engineers might well follow shipbuilders in this respect. The fact that failures of small span under bridges were never heard of, he considered, indicated that these structures possessed a very considerable reserve of strength. He thought the impact question had been solved by the bridges themselves, but that corrosion was certainly a difficult matter, and he finally

remarked that bridge engineers should not be hampered by any rules which had been hurriedly drawn up.

Mr. R. W. Western here remarked that advantage should certainly be taken of the work done by the old engineers who had produced safe structures with very imperfect means. Engineers responsible for the safety of bridges were very much alive to the danger of a fiasco, and when in doubt were apt to play for safety. A structure designed by a predecessor was examined, and additions were made to the subsequent structure—a process which might be repeated more than once. In this way the capital cost was greatly increased, a most important consideration at the present time when capital was much more difficult to obtain than was formerly the case.

In his reply, Mr. Wilson, in answer to Professor Lea, pointed out that Fairbairn had tested a large model of the Britannia Bridge and first obtained a load-deflection curve for the vertical loads. He then turned the model on its side to obtain the load-deflection curve for the wind loading. The first part of the second curve, however, was not a straight line owing to the fact that certain movements of the rivets occurred in the first loading, and these had to be taken up before normal conditions were reached in the second test. The speaker regarded this fact as a reflection on the $\frac{I}{Y}$ formula in the case of a riveted structure. He also mentioned that Fairbairn had made a fatigue test of a riveted girder, using for the purpose a water wheel which applied the load at the rate of about eight times per minute. The time required for a complete test was, of course, very great, but the results were useful.

After the chairman had proposed a vote of thanks to the authors and speakers in the discussion, which was carried with acclamation, the morning session terminated, and, in the afternoon, the section visited the canister works of Messrs. Reckitt and Sons, Limited, at Stoneferry.

The Works of the Humber Portland Cement Company.

The first item on the programme for the meeting of Friday, the 8th instant, was a paper by Mr. G. V. Maxted and Mr. F. Knott, entitled "The Equipment of a Modern Cement Works, with Special Reference to the Works of the Humber Portland Cement Company." The paper, which took the form of a lantern lecture, was delivered by Mr. Maxted, who, after referring to the many uses of Portland cement, mentioned that Hull was an important centre of the industry, possessing four cement works, of which those of Messrs. G. and T. Earle have a weekly output of nearly 5,000 tons. The works of the Humber Portland Cement Company, to which special reference was made, are situated at Melton and have now been in operation for about a year. The raw materials employed are indurated chalk and alluvial clay, both of which are found near the site, the former being excavated by a Bucyrus digger and the latter by a Priestman grab bucket. The chalk-crushing plant comprises a No. 9 Allen gyratory crusher driven by a 150 h.p. motor, and from this crusher the chalk falls into a screen which removes the larger pieces and passes them directly into a 30 in. by 18 in. jawcrusher. The crushed chalk is then delivered by a bucket elevator into a ferro-concrete storage silo having a capacity of 3,000 tons, which is sufficient to maintain a continuous supply when repairs to the crushing plant have to be carried out. From the silo the crushed chalk passes into two large compound grinding mills, in which a certain quantity of water is added and a chalk slurry produced, the slurry being afterwards pumped through a pipe line 1¼ miles in length to the main plant. Here the slurry is delivered into a sun-and-planet type mixer, 66 ft. in diameter, and of sufficient capacity for the production of about 800 tons of cement.

The clay, which is excavated by a Priestman grab, is hauled over a 3 ft. gauge railway to the wash mills at the works, where the chalk slurry and the clay are mixed together, suitable arrangements being provided to ensure that the proportions of the two materials are such as to give the required analysis. The mixed slurry is then ground in two tube mills and afterwards pumped into six large air-agitated storage tanks, from which it is delivered into the measuring appliance placed at the upper, or inlet, end of the rotary kilns. There are two of these kilns, each 200 ft. long and 9 ft. in diameter, and at the upper end of each large brickwork dust-settling chambers have been constructed to collect the dust which issues with the fumes from the kilns. Later, when the works are finally completed, the dust from these chambers will be removed and returned to the kilns by mechanical means. The kilns are fired by coal dust in the usual way, and the resulting clinker falls from the kilns into rotary coolers. At present the cooled clinker is lifted into a storage silo by means of a Priestman grab, but purely automatic arrangements for handling the clinker will be installed later. The clinker is ground in tube mills, and the resulting cement is now stored in bins from which it is delivered to the automatic packing machines by extractor screens. Two packing machines of American manufacture are installed, each having a capacity of 30 tons per hour, but otherwise the plant has been manufactured by Messrs. Edgar, Allen and Co., Limited. At the conclusion of Mr. Maxted's lecture a series of kinematograph films, showing the whole process of cement manufacture at the Melton Works, was exhibited.

The Resistance to Fire of Concrete and Ferro-Concrete.

There was no discussion on Mr. Maxted's paper, and the next item taken was a paper by Professor F. C. Lea and Mr. R. E. Stradling, bearing the title quoted above. This paper, which was read by Mr. Stradling, describes a series of experiments carried out in the Department of Civil Engineering at the Birmingham University with the object of investigating the effect of high temperature on Portland cement concrete, both plain and reinforced. We commence to reprint the paper on page 341 of this issue, so that we need not refer to it in greater detail here.

After the paper had been read by Mr. Stradling, Professor Lea, who was invited by the Chairman to speak, said there would be but little time for criticism of the paper, but he wished to anticipate any criticism which might be levelled at the small scale of the experiments. The speaker pointed out that large sums had been spent in this country, in America and elsewhere, in making full-scale experiments with the object of finding the most suitable constructional material to resist fire, but the results achieved had not been commensurate with the expenditure. When invited by the Government to join the British Fire Prevention Committee, he had suggested that large-scale experiments should cease, and that money should instead be spent on fundamental research work, of which the paper was an example. They were now endeavouring to establish the fundamental conditions which determined failure or success, and he hoped the work would be carefully considered by engineers, architects and chemists, since the subject was one of great economic importance. The above remarks, he concluded, explained the *raison d'être* of the small scale experiments.

The only speaker on the paper was Dr. J. S. Owens, who referring to the loss of water at 100 deg. C. shown in Fig. 8 of the paper, said this was apparently due to the evaporation of water not in chemical combination. Fig. 10, Dr. Owens continued, showed a steady increase of strength between 0 deg. C. and 100 deg. C., up to about 25 per cent. at the latter temperature, and he asked if that were a purely physical effect due to the removal of the water. He also enquired if the effect would have been the same if the specimen had been merely dried in a desiccator. The speaker mentioned that he had read a paper at the Dundee meeting of the Association, 1912, dealing with the effect on stone of the absorption of water and had found a loss of strength of about 30 per cent., which he took to be a physical effect.

Time did not permit the authors to reply to these points, and the chairman then proposed a vote of thanks to the authors of both papers, remarking that a visit would be paid to the works of the Humber Portland Cement Company that afternoon when the members would have ample opportunity of obtaining any additional information they might desire.

Some Australian Railway Problems.

The only other business for the morning's meeting was the delivery of the presidential address bearing the above title by Professor T. Hudson Beare. This address we deal with elsewhere in this issue, but before delivering it, Professor Hudson Beare said he wished to explain a few points. The whole of the Australian railways, with the exception of a few miles, he said, were state-owned and they consisted, for the most part, of single-line track. Previous to the confederation, the lines were owned by the individual States, each State managing its own system. When confederation came, the lines were still left in the hands of the individual States, but the Commonwealth Government agreed to construct the great Transcontinental lines, one of which, connecting Port Augusta, Fremantle and Perth, was already constructed. Without considering Tasmania there were thus five State railway authorities and the Commonwealth authority as well.

At the conclusion of his address, Professor Beare remarked that he proposed to depart from precedents by inviting members to discuss the address or to ask questions. To this invitation Professor Lea responded by remarking that in this country changes would have to be considered more in relation to goods traffic than to passenger traffic, to which Professor Beare seemed to have confined his attention. The speaker assumed that the gauge problem in Australia had been carefully considered from the point of view of goods traffic, and that the change to 4-ft. 8½-in. gauge offered the best solution. There were many economic advantages, he added, in changing from 5-ft. 3-in. gauge to 4-ft. 8½-in. gauge, but to change in the other direction would obviously be extremely difficult on account of the alterations required to bridges, tunnels, &c. He also inquired if the change had been considered in relation to possible future developments in connection with electrification of the lines.

The only other speaker, Mr. J. S. Wilson, inquired whether the proposed change entailed alterations to existing rolling stock to enable it to run on lines of different gauges or whether the construction of entirely new stock would be necessary. To these queries Professor Beare replied that he had referred to the vital question of goods transport in a part of his address that he had omitted to read. He added that he gathered from the most recent report that the decisions had been reached mainly from the point of view of goods traffic. With regard to electric working, he remarked that it might be possible to produce electric power for the purpose from the brown coal in the country. To Mr. Wilson's question as to rolling-stock, he replied that some could be converted, but the greater part would have to be of new construction.

Professor Lea then proposed a vote of thanks to Professor Beare for his address and, after the vote, which was put to the meeting and duly carried, had been acknowledged by Professor Beare, the proceedings terminated.

Economic Steam Production.

When the section re-assembled on Monday, the 11th inst., the chairman, Professor T. Hudson Beare, explained that the subject for discussion was the economic production of steam, with special reference to marine practice. Four communications on the subject, he said, had been received and he proposed to ask the authors of the papers to read them in succession; the discussion on the four papers, he added, would then be taken together. The first paper read was that by Dr. C. H. Lander, entitled "Home-Produced Oil Fuel," and before reading it the author explained that it was intended to be a semi-official communication to the Association of the views of the Fuel Research Board. This paper we reprint on page 348 of this issue, so that we need not refer here to the nature of its contents. The next paper taken was one by Engineer-Commander Fraser Shaw, R.N., dealing with economic steam production and referring particularly to marine practice, and this was followed by a similar communication by Engineer-Commander R. Beeman, C.M.G., R.N., dealing with the subject from the naval point of view. These two papers

will be found on pages 349 and 346 respectively, but, we may mention that in reading his paper Commander Shaw added that the weight of a gas-fired boiler to develop 3,000 h.p. would be 100 tons when filled with water, and that the weight of a boiler to develop the same power by hand firing with coal would be 300 tons. There would thus, he said, be some 200 tons to spare to allow for the weight of the producers. The remaining paper by Mr. A. Spyer is also reprinted on page 344.

Invited by the chairman to open the discussion, Professor Sir J. B. Henderson referred to the economic importance of the subject and inquired as to the weights of the producer gas-fired boiler installation mentioned by Engineer-Commander Fraser Shaw.

Mr. C. E. Stromeyer, who followed, took exception to Mr. Brownlie's figures as to the inefficiency of land boilers quoted by Commander Shaw, pointing out that Mr. Brownlie had only been called in to investigate cases in which steam users were dissatisfied with the results they were obtaining. The speaker mentioned that he had tested a number of installations some years ago and had prepared statistics for these cases in which much higher efficiencies were obtained—efficiencies which were nearer what he regarded as the practical limit of about 75 per cent. Endeavours to increase efficiency beyond that limit by forced draught and other expedients, he thought, were often negatived by increased wear and tear, so that the extra cost of repairs and maintenance exceeded the saving in fuel consumption. He also questioned the figures for efficiency given for boilers fired with liquid fuel, pulverised fuel and gas, and inquired whence these figures had been obtained. In one test with pulverised fuel which he had carried out, an efficiency of over 100 per cent. had been obtained, but the result had afterwards been accounted for by heat given up by the brickwork. The high flame temperatures obtained with pulverised coal and oil, often caused trouble with the brickwork and tubes.

With regard to gas firing, he knew of a case in which its application had resulted in increased thermal efficiency, but had reduced the output, and he had come across an instance in which the change from coal to oil fuel had given both reduced efficiency and reduced output. This, he explained, had occurred with internally-fired boilers of the Lancashire type, and he suggested that it was due to the fact that the flames came into contact with the comparatively cool heating surface of the boiler before the combustion had been completed. Forced draught had many advantages, but engineers were sometimes inclined to overlook the fact that steam had to be used in engines of low efficiency for producing the draught, so that the overall efficiency of the installation was less than would appear at first sight. As to the unsatisfactory conditions under which firemen worked, as mentioned by Commander Shaw, the work was certainly arduous, but he thought that many of the ordinary seamen would be found willing to change places with the stokers. On Mr. Spyer's paper, Mr. Stromeyer remarked that Knoblauch's experiments were first published in 1907, and these, he thought, were more valuable than those referred to by the author, which were published in 1911. The measurement of the specific heat of steam was one of the most difficult subjects that the physicists could undertake, and he understood that the chief difficulty was the measurement of the temperature of the steam. In conclusion, with regard to the statement in Mr. Spyer's paper that no difficulties were encountered with high pressures and temperatures in turbines, he knew of one case in which very decided troubles had arisen from the use of steam at 360 lb. per square inch at a temperature of 700 deg. F.

Sir Westcott Abell, who was then invited by the chairman to speak, said he thought from the point of view of the ordinary trading ship that the choice of propelling machinery lay between the triple-expansion engine with coal-fired cylindrical boilers and the Diesel engine. Excessive refinements, he added, were very difficult to apply in the case of a tramp steamer which had to employ a great variety of fuels. He thought the most valuable suggestion in the papers was that in Mr. Spyer's paper relating to mechanical stoking. There were many difficulties in the way of its adoption, but if a satisfactory system could be evolved it would be of great assistance to the maritime transport of the British Empire.

The only other speaker in the discussion was Professor G. G. Stoney, who remarked that high temperatures and pressures had certainly caused considerable trouble in steam turbines. Cast-iron, he added, should not be used at temperatures higher than 450 deg. F.; for higher temperatures, steel or other materials should be employed. Differences in temperature between one part of a turbine and another caused even greater difficulties than high temperature *per se*. In a modern land installation using turbines supplied with steam at 350 lb. per square inch and 750 deg. F. exhausting into a condenser at 80 deg. F., the temperature range would be 670 deg. F., and such a range in a single cylinder would give considerable trouble. The difficulty could, however, be greatly reduced by employing two turbines in tandem, when about two-thirds of the total temperature drop would occur in the small high-pressure cylinder and the remainder in the larger low-pressure cylinder. The speaker also referred to the trouble experienced in boilers working at very high pressures from the dissolution of the gauge glasses. In turbines, he added, difficulties were encountered in connection with the blading which required very careful design. Troubles with high temperatures could, however, be relieved by employing an impulse wheel at the high-pressure end.

No other member wishing to take part in the discussion, the chairman then asked the authors of the papers to reply to the points raised by the speakers. To this invitation Dr. Lander remarked that he had but little to say in reply, since no criticism had been made of the paper for which he was responsible. He added however, that the problems which remained to be solved in connection with home-produced oil fuel were not purely chemical. Fuel oil and smokeless fuel could be produced together with a very rich gas having a calorific value of about 1,000 B.Th.U. per cubic foot, and the most important problem to be solved was the production of cheap retorts which would stand up to the work. Metal, he continued, could be employed for temperatures up to about 600 deg. C. but for higher temperatures refractory materials had to be employed and difficulties were then encountered owing to leakage. With the cast-iron retorts used for temperatures below 600 deg. C. there were difficulties owing to the growth and burning away of the metal, and also owing to the lack of knowledge as to the behaviour of metals at high temperatures. In this connection, Dr. Lander mentioned that difficulty had been encountered at the Fuel Research Station owing to a slight creeping which occurred in metal under stress at high temperatures. The metal, he added, although showing a perfectly definite yield-point, appeared to be plastic, to some extent, at 600 deg. C., and actual extension took place under stress at that temperature. The difficulties were thus more on the engineering than on the chemical side.

At this point, Professor F. Bacon remarked with regard to that part of Engineer-Commander Fraser Shaw's paper which called attention to the necessity for knowing the proportion of CO in flue gas, as well as that of CO_2, that there was now on the market a type of CO_2 recorder which supplied this information. In this instrument, he said, every alternate sample of flue gas, before passing into the absorber, was passed through an electrically-heated tube containing copper oxide. Any CO present was in this way changed into CO_2 and added to that already present in the flue gas. The presence of the CO would be made evident by the difference in length of alternate lines drawn by the recording part of the instrument.

Commander Shaw, who then replied, said, in answer to Mr. Stromeyer, that he was glad to hear that boiler efficiencies as high as 75 per cent. were attained in land practice. The figures given in his (the speaker's) paper for the efficiencies of boilers fired with liquid fuel, pulverised coal and gas had been obtained from various sources, but would apply only to boilers with furnaces specially designed for the particular fuel and not to converted boilers. He thought there could not be much question as to the figure of 84 per cent. given for liquid fuel, and added that the figure of 80 per cent. for pulverised coal was given in the latest publication on the subject by the Canadian Government. The figure of 90 per cent. for this fuel had been given to him by the chief mechanical engineer of the United States Bureau of Standards, and the figure of 85 per cent. for gas fuel was that guaranteed by the makers of a certain gas-fired boiler. He added that he had himself obtained a figure of 83 per cent. for gas firing on a boiler worked at less than its maximum capacity. With regard to the use of liquid fuel in Lancashire boilers, he thought that, in the case referred to by Mr. Stromeyer, the wrong form of sprayer must have been employed. If the oil struck the water-cooled surfaces, bad combustion would certainly result, but it was quite possible to design a sprayer to produce a long flame which would travel along the flue without coming into contact with the sides. He thought his remarks as to the working conditions for firemen had been misunderstood. The conditions, he said, were such as to prevent the best type of men from undertaking the work, but his remarks applied as much to seamen as to firemen.

Commander Beeman having no comments to make, Mr. Spyer then replied to that part of the discussion referring to his paper. He first remarked that it was difficult to increase economy in steam production, the efficiency of which was already in the neighbourhood of 80 per cent. Much more, he thought, could be done in connection with the utilisation of steam. The opinion was held in some quarters that oil was replacing coal as a fuel for steam raising, but this was not really the case. During the coal strike many land boilers had been altered for oil burning, but most of these had now been re-converted for burning coal, since it did not pay in land installations to burn oil. With regard to the use of oil fuel containing a considerable percentage of sulphur, this element had a very deleterious effect on the heating surface in proximity to the flame. He thought the use of pulverised coal would be practically impossible in marine practice, but would be interested to hear more on the subject. He agreed with Commander Beeman that some 65 per cent. to 70 per cent. of the heat absorbed by a boiler was in the form of radiant heat and referred to some experiments by Niclausse on the evaporation of successive rows of tubes in a water-tube boiler. These experiments had shown that 70 per cent. of the total heat transmitted to the water was absorbed in the first five rows of tubes. With regard to the use of high temperatures and pressures in turbines it was true that difficulties existed, but it was certain that turbine makers in this country would now use steam at 350 lb. per square inch and at 750 deg. F. if required to do so. This, was Continental practice, and the Continental makers were prepared to guarantee results.

The chairman, in bringing the discussion to a close said he wished himself to make a few remarks. First, he pointed out that in Dr. Lander's paper both Fahrenheit and Centigrade temperature scales had been referred to. He thought it highly desirable that engineers should adopt one or the other of these scales, and use that only, in order to avoid the confusion which arose from the use of both indiscriminately. Another point was that economy in the generation of steam should be considered not only from the point of view of boiler efficiency, but from the efficiency of the whole plant. It by no means followed that an increase of 2 per cent. or 3 per cent. in boiler efficiency would give a corresponding increase in the overall efficiency which might even be reduced. He also pointed out that the advantages of feed-water heaters, superheaters, &c., could not be measured merely in terms of increased efficiency. Such appliances led to better working of the plant and reduced working costs and upkeep by reducing strains in boilers and temperature stresses, and it might well pay to lose a little in efficiency if improved running could be obtained. Like Mr. Stromeyer he had been surprised at the low figure of 55 per cent. given for the efficiency of land boilers. Plants could certainly be found with absurdly low efficiencies, because owners did not always realise the cost of the fuel wasted, but such

cases did not represent the average. Intelligent supervisors were employed in the majority of plants because owners had found that it paid to do so. In conclusion, the chairman remarked that whether oil fuel eventually replaced coal depended largely upon the work of the Fuel Research Board. He thought the public would be willing to bear the slightly increased cost of the smokeless fuel produced, since the atmospheres of the cities would be so much improved by its use.

After a vote of thanks to the authors of the four papers had been proposed by the chairman and carried, the meeting adjourned, and in the afternoon the members paid a visit of inspection to the works of the National Radiator Company, at Perth-street, Hull.

(To be continued.)

THE IRON AND STEEL INSTITUTE.

(Concluded from page 304.)

ON the members re-assembling in the Tempest Anderson Hall, Yorkshire Philosophical Society, York, on the morning of Wednesday, the 6th inst., the first paper taken was on

SOME EXPERIMENTS ON THE FLOW OF STEELS AT LOW RED HEAT, WITH A NOTE ON THE SCALING OF HEATED STEELS,

by Mr. J. H. I. Dickenson, who read it in abstract. We commence the reproduction of this paper on page 326 of our present issue.

As will be seen, the paper dealt with long duration tensile tests of various steels at low red heat, made in order to arrive at the best material for containers capable of withstanding considerable stress at high temperatures after long periods. It was found, the author stated, that all the steels investigated behaved very much like highly viscous fluids at temperatures well below the critical range, and could not be said to have any definite tensile strength at low red heat. The results showed that all the samples had behaved in accordance with the law governing the change in viscosity with temperature. Here, he added, that an interesting speculation arose as to whether if the curves giving duration against temperature did represent a law, why that should not obtain down to much lower temperatures. It might, however, be comforting to note that the time to produce rupture at atmospheric temperatures under the same conditions of loading worked out at an enormous amount of years.

Mr. H. Brearley, who opened the discussion, congratulated the author on his patience in carrying out tests of such long duration, the results of which would very considerably extend our knowledge on the behaviour of steels at high temperatures. He (the speaker) suggested that the author was rather hard in criticising former work on similar lines but of much less duration, as meaningless and misleading. The former workers had been seeking to arrange the materials in the order of their tensile strength at high temperatures. One thing he (the speaker) missed in the paper was a form of stress-strain diagram of a material taken at a high temperature. The tensile test was a test which had been devised for wrought iron, for which it had a meaning, and it was an inheritance which the steel age had received from the iron age. The author's tests in the hot state were different from those made in the cold. He (the speaker) fancied that if an autographic test record accurately made had been taken it would have contained almost all the information which the author had so laboriously collected. An interesting point in the matter of the properties of steel at high temperatures had relation to the difficulty or ease with which it could be dealt with under the rolls, the hammer and so on. Mr. Brearley then exhibited a number of small bars which had been heated at one end, the heats tapering down to the other end; these bars had been twisted, and one would expect that they would twist most where they were hottest, but that was found not to have been at all the case, the shortest pitch having been where the piece was cold. He asked the author whether he could give an explanation for that occurrence.

Mr. J. H. Whiteley dealt mainly with the second part of the paper covering the scaling of steels at high temperatures, and questioned the function the author brought in in connection with his diagram, Fig. 19. The circumstances under which he (the author) arrived at this function had to be considered; he had, in the first place, variations in the conditions of his furnace, also various kinds of furnaces, but he counteracted the conditions by rotating the specimens in the furnace. Did the author, he asked, take precautions to see that the scale did not fall off in some instances. The author also referred to the fact that metallic iron could be included, as had been described by Stead; that introduced a great cause of error, said Mr. Whiteley, in connection particularly with the author's statement as to the method he followed "in order to maintain a practically uniform rate of oxidation, which slowed down as adhering scale increased in thickness." Further data were required at this point. There was little doubt that when a coating of oxide was formed there was a reduction of iron oxides by ferric iron, and the rate of scaling depended upon the rate at which oxygen could penetrate under the scale and reach the iron behind it. The action and uniformity of the scaling depended upon the rate of penetration of the oxygen combined with the rate at which reaction took place.

In the course of his reply, and with reference to Mr. Brearley's remarks, Mr. Dickenson paid a tribute to his assistants who had been unremitting in their care of the test work during its progress. He felt sure there was in the subject a large field for further investigation. Mr. Brearley had suggested that he had been hard on previous tests made by others and with rapid loading. It was not his (the speaker's) intention to be hard upon anyone, but there were many pamphlets being issued at the present time, stating that such and such a steel was better than any other because it had a tensile stress of so many tons at a temperature of so many degrees, and the matter should be put forward in the right light. In other words, more should be done than carrying out tensile tests at high temperatures in a similar way as obtains in the cold, and this for the aid of designers who had to build containers for withstanding high stresses and high temperatures and required the information. He would have liked to include in his paper an autographic diagram to show the behaviour of his test specimens, but he had no time to deal with it on this present occasion; he did not think, however, it would give all the information actually contained in the paper. The conditions of loading might perhaps yield a curve not unlike that for cold steel. The behaviour of steel under rolls or under the hammer was important, he admitted, but the subject covered by his paper was important also. In regard to Mr. Brearley's twist tests he was not able to give an explanation; the result of these tests did not seem to fit in with his (the author's) work, but he would repeat Mr. Brearley's experiment to see what was the occurrence in twisting the bar. It struck him that it was possibly necessary to keep the brace absolutely in a line with the specimen in course of twisting—he did not know, but he would carry out this twisting test. The function which Mr. Whiteley had alluded to fitted in with the facts, although the experiments may perhaps not have been so perfect as would be necessary for arriving at an absolute proof. By rotating the test pieces the best was done that could be. He would deal with the rates of oxidation, of penetration of oxygen by correspondence.

PRACTICAL NOTES ON THE MANUFACTURE AND TREATMENT OF HIGH SPEED STEEL.

The second paper taken at the meeting on Wednesday morning was the one having the above title, by Mr. H. K. Ogilvie. In the latter's absence it was read in abstract by the secretary. We shall reproduce it in a forthcoming issue.

The paper dealt mainly with the manufacture of high-speed steel in the basic-lined electric furnace. The crucible method of making the steel, it added, was of little technical interest, being only a melting operation, as no refining was possible. The labour and fuel costs were extremely high, but the plant and overhead charges were much lower than in the case of the electric process. The author also referred to the class of scrap to be used, and to the fact that in the crucible it occasionally occurred that small particles of the tungsten compound were not completely melted, particularly when tungsten powder was used.

Mr. C. G. Carlisle thought the author made rather an illogical statement when saying that the two methods—electric furnace and crucible—were equally good, and adding that in the crucible some particles of the tungsten powder remained unmelted. This latter condition obtaining in the crucible, it was obvious that the two processes were not equal, and the electric process was therefore the better one. The author had also specified a time limit for his charges, saying that the time should not exceed 4½ hours for a 3-ton or 4-ton furnace. Occurrences might lead to upsetting all calculations in that respect, and the statement pandered to the commercial instinct rather than to the technological. From the metallurgical point of view, the author had not sufficiently enlarged upon the gas trouble; there were no electric furnacemen who had not been exasperated by it. The author's slag was not all right when he had his gas trouble. An over-oxidation of the bath was perfectly possible through an oversight; too much oxygen was added in the form of oxide of iron, some was left in when the slag was raked off and persisted during the successive refining. In the early stages, when there was insufficient fusibility, the slag was lumpy, part of the metal surface was unprotected by a slag layer and the arc playing directly upon the metal led to trouble. He questioned the author's way of treating his billets, and was surprised he did not anneal or temper his tools before final hardening.

Mr. H. Brearley found the paper a straightforward contribution, although the economical conclusions were perhaps not quite clear. The author had compared the electric with the crucible process, but had not stated what was the crucible process he had referred to. In Sheffield the sound bar cost was practically the same for both the gas-fired crucible and the electric process. He was inclined to agree with the author that it was preferable to use tungsten metal rather than powder. He (the speaker) could not understand why it was not commercially possible to use turnings in this country when it was possible elsewhere. The author had referred to two steels, one easily filed whilst having a Brinell hardness of 650, and one impossible to file although the Brinell number was not over 550. This was rather startling, and he suggested that the members would like these two specimens to be shown them.

Mr. V. Stobie also questioned the author's remarks in regard to the use of turnings, adding that one could not go on making high-speed steel from turnings, and a start had to be made in manufacture, using raw materials.

The last paper dealt with was one entitled

THE CHANGES OF VOLUME OF STEELS DURING HEAT TREATMENT.

which was contributed by Mr. Leslie Aitchison and Mr. G. R. Woodvine. In the absence of both authors it was read in abstract by the secretary. The paper stated that the work was proceeding, and it was hoped that further reports would be presented shortly, when an explanation of the observations and their practical bearing would be entered into.

Mr. Saniter found that the authors had spoken of volume right through the paper, when they were only dealing with longitudinal expansion and contraction. The true volume changes, which could be easily arrived at, were not given and the results were obscured thereby.

A vote of thanks to the City authorities and to the Yorkshire Philosophical Society, with whom was coupled the name of Dr. Walter E. Collinge, the Keeper of the Museum, terminated the proceedings.

PERSONAL.—The new London address of Ironclad Switchgear Company, Limited, is 23, Queen Anne's Gate, Westminster, S.W. 1. The London Office will deal with inquiries and orders emanating from South Wales, Midlands, East Coast, Southern Counties and Overseas. Large London stocks are being prepared and will be ready within a few days.—Messrs. D. Anderson and Son, Limited, of Manchester, London and Belfast, makers of the "Belfast" Roofs, Roofing Felts and "Sidol" Wood Preservative, inform us that they have established their administrative headquarters at Park-road, Stretford, Manchester, where all correspondence should be addressed.

NOTES ON NEW BOOKS.

A BOOK, which has for its object the demonstration of the necessity for a knowledge of the principles of geology to the mining engineer and of the part which it plays in his work, is entitled *Géologie et Minéralogie Appliquées á l'Art de l'Ingénieur*, by L. de Launay, Professeur à l'Ecole des Mines et à l'Ecole des Ponts et Chaussées, Membre de l'Institut. It forms part of the "Grandes Encyclopédies Industrielles," and is published by J. B. Baillière, 19, Rue Hautefeuille, Paris, at the price of 40 francs. While pointing out that the theoretical side should not be entirely neglected, even if it were in no wise necessary for an understanding of the practical application of geological principles, the author confines himself so far as possible to the points of practical necessity and interest. Thus, the chapter on palæontology, which is illustrated with admirable sketches of typical fossils, is practically confined to descriptions of the hard parts of the organisms, that is to say, the structural portions generally found preserved. Since stratigraphy is dealt with at length in most of the elementary treaties on geology, the examples selected for discussion in this are almost exclusively French. The concluding chapter of this portion deals with earth movements and their effects. The second portion commences with a discussion on geological maps. Although French maps are taken as illustrations, the general methods apply equally to those of other countries. The discussion on tunnels is illustrated by a review of the possibilities of the Channel Tunnel, as an example where the geology is comparatively simple. The points brought out in the construction of such tunnels as the Saint-Gothard and Simplon, where the region was geologically extremely complex, are of particular interest to the engineering student. The final chapter deals with subterranean waters, including their infiltration, circulation and ultimate reappearance.

In spite of all the attempts to dislodge it, the lead storage battery easily holds its own as the most successful form of secondary cell where large powers are concerned, and where efficiency is imperative. It has its faults and some of these are very serious ones, but nothing yet has been devised which will perform its functions more advantageously. In "*The Lead Storage Battery*," by H. G. Brown (London: The Locomotive Publishing Company, price 5*s.* net), the construction and characteristics of the modern lead cell are clearly explained and useful advice is given as to the operation of batteries. The author describes the apparatus used in a battery room and the periodical records which should be kept. A useful chapter on the testing of batteries for capacity, and the cadmium test for defective cells is included. The book is of a thoroughly practical character and being inexpensive it might well be placed in the hands of every operator who has the responsibility for the care of storage batteries, large or small.

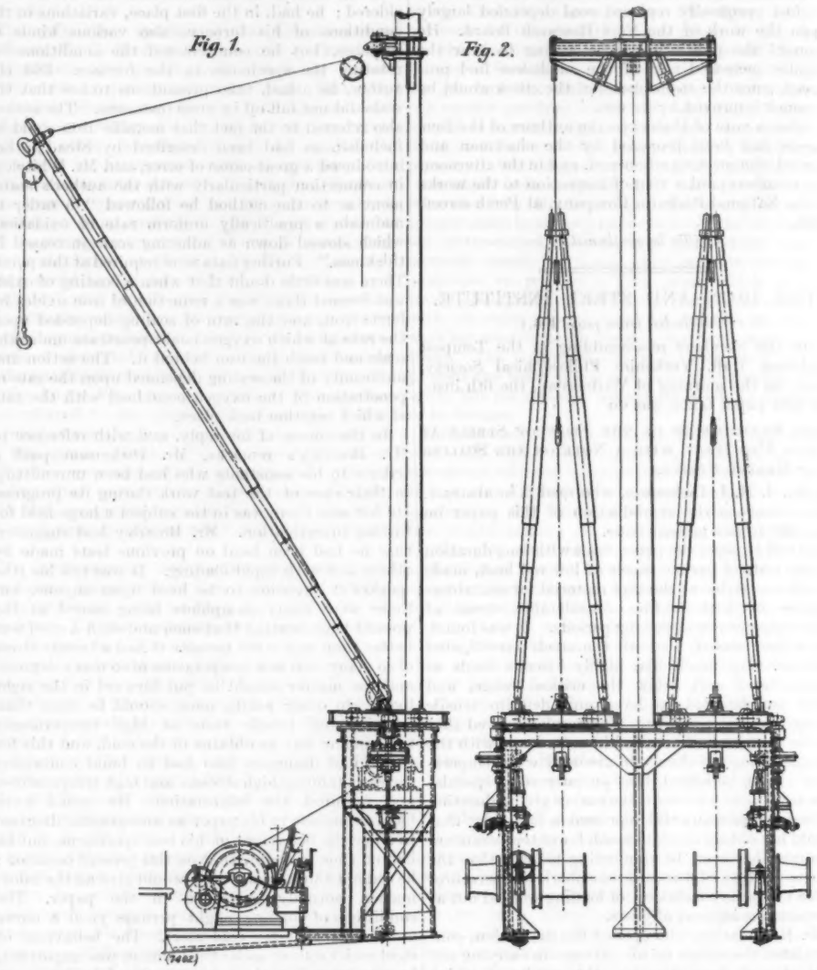
It has always been recognised that the annual loss by fire in the United States is enormous. The National Board of Fire Underwriters state that during the period 1900 to 1909 inclusive, during which time the Baltimore and San Francisco conflagrations took place, the average yearly loss was 217,000,000 dols. That matters are not getting much better is shown by the fact that the average annual loss mounted to nearly 300,000,000 dols., during the five years from 1915 to 1919 inclusive. The figures are quoted in the preface of the revised edition of "*Fire Prevention and Fire Protection as applied to Building Construction*," by Joseph Kendall Freitag (London: Chapman and Hall, price 30*s.* net). The book is really a manual for Architects, dealing as it does principally with the methods of making fire-resisting buildings, and the materials of construction which are advisable. Warehouses, residences, schools, theatres, garages, &c., all come under review and the treatment appropriate to each is discussed in detail. Sprinkler systems and automatic alarms are also dealt with. As a compendium of architectural practice with regard to fire-resisting construction, the book appears very complete, and with its thousand pages and nearly four hundred illustrations, it touches on practical matter which comes within the scope of its title. It is an American work and may be taken as representative of the best American practice.

The weaving of cloth is probably a more fundamental industry, even than agriculture, and the higher the level of civilisation, the more varied and refined become the textile arts. In spite of the daily contact of every person with woven goods, it is surprising how badly informed the general public is with the numerous and intricate processes involved in the production of the clothes he wears. In "*Textiles*" (Constable and Company, Limited, London, 1922; price, 15*s.* net), the author of which is Professor A. F. Barker, of Leeds University, the reader will find an interesting general account of the whole textile industry, the ground being covered probably as well as is possible in a single volume. After a brief chronological account of the leading inventions of the industry, the book deals with the production of the raw wool, silk, cotton, flax, &c., then with mercerised cotton and artificial silks, which have had such important developments in the trade. Dyeing, spinning and weaving are next treated and considerable space is devoted to the principles of designing and colouring. Associated with the author in the production of the volume are Messrs. W. M. Gardner, R. Snow, W. H. Cook and F. Bradbury, each of whom contributes a section on his special subject. The book is well worth acquiring by students and others interested in textile work and processes. It is eminently readable, but it might be made even better by the addition of a glossary of the numerous technical terms with which the industry abounds.

MÜLLER'S ROTATING CARGO-HANDLING DERRICKS.

CONSTRUCTED BY MESSRS. FIGEE BROTHERS, ENGINEERS, HAARLEM.

Fig. 1. *Fig. 2.*



ROTATING DERRICKS FOR HANDLING CARGO.

THE usual method of getting cargo into and out of ships' holds is in many respects somewhat crude and cumbersome. Slinging the load from one derrick to another after it has been hoisted, or slewing a single derrick by men hauling on ropes, are the alternatives generally employed. A much more mechanical method has been adopted in certain of the vessels of the Koninklijke Paketvaart Maatschappij, of Amsterdam, and this we illustrate in Figs. 1 and 2, on this page. The design is due to Mr. William Müller, chief engineer to the company, the construction of the apparatus being carried out by Messrs. Figee Brothers, of Haarlem.

At the foot of the mast is a small gantry on which a pair of derricks are mounted. Each derrick has two booms, much the same as a shear-legs, the feet of these booms being fixed to a table which can be rotated by gearing almost through a complete circle. Each table is driven by a small vertical steam engine bolted to the side of the gantry. The engines are controlled by the men at the winches, and each engine is fitted with a hunting arrangement, similar to that employed with steam steering gear, which stops it automatically when it has turned the derrick through the predetermined angle. The rope from the winch passes up through the centre of the turntable, so that it lies practically in the plane of the derrick booms in whatever position they may be. The winch operator has a full view of the load, which he can raise, slew and lower as he may desire.

PRICE INCREASES IN GERMANY.—The Commercial Secretary at Cologne has forwarded to the Department of Overseas Trade a number of extracts from the German press dealing with price increases of castings and fittings, coal, rolled and pressed leaden ware, cement, pig-iron, and brass plates and rods. The prices can be consulted at the offices of the department.

GROUPED REPRESENTATION IN FOREIGN MARKETS.—The Federation of British Industries in suggesting that groups of British firms in non-competing lines should constitute themselves into limited liability companies for the purpose of conducting their own sales organisation in overseas countries, says that the action of a number of firms in the United States who have recently combined their export departments with a view to securing increased efficiency and reduced expenditure in the conduct of their foreign business, supplies an interesting indication of the growing recognition of the value of concerted effort. The products of the companies concerned include concrete and paving mixers, woodworking machinery, logging and construction tools, trucks, marine engines, electric lighting plant, carburettors and thermostats, sanitary woodwork and bathroom plumbing fittings, garage equipment, &c.—allied but non-competing lines.

THE RESISTANCE TO FIRE OF CONCRETE AND REINFORCED CONCRETE.*

By Professor F. C. LEA, O.B.E., D.Sc., M.Inst.C.E., M.I.Mech.E., and R. E. STRADLING, Ph.D., M.Sc., Assoc.M.Inst.C.E.

REINFORCED concrete structures are very common in these days, and buildings made of this material are frequently referred to as fire proof. In this country, as well as on the continent of Europe, and the United States of America, disastrous fires have, however, frequently proved that providing a fire rages for a considerable length of time, as is the case often in large warehouses, these structures fail badly, and in many cases it has been necessary to dismantle the buildings completely.

In 1920 one of the writers presented a paper for discussion at the meeting of "G" Section of the British Association, in which details were given of a few preliminary experiments carried out (in the Civil Engineering Department of the University of Birmingham) in the hope of elucidating the problem as to what happens when concrete structures are exposed to high temperatures. During the intervening years further work has been done, the expenses of which have been defrayed by a grant from the Department of Scientific and Industrial Research, and the purpose of this paper is to give a summary of the results obtained. The full details of the experimental work will be found in a brochure published by the Government department concerned.

In considering the effect of fire upon reinforced concrete the problem can be stated under two headings :—

(1) Is it possible to make concrete which shall retain its strength during and after exposure to the high temperatures liable to occur in a building fire ?

(2) Is it possible to prevent the steel from reaching such a temperature that its strength is reduced to, or below, that required to carry the loads occurring in the building ?

In the paper presented to the Association in 1920 and in other† published papers, one of the authors has shown that mild steel at temperatures of little more than 600 deg. C. has a very low breaking stress, and that assuming the concrete itself conducts heat sufficiently to allow the temperature of the steel to rise to more than 600 deg. C. a loaded structure is almost bound to fail. Certain data were also given as to the conducting power of concrete, and it was there shown that when the surface of concrete is exposed to certain temperatures for periods of from one to four hours the temperature of steel at given distances from the heated surface reached the dangerous temperature, and subsequent tests which will be published elsewhere have confirmed the results obtained. It was also shown that the concrete itself was very seriously affected by exposure to temperature, and it was then suggested that investigations were desirable to determine the causes of failure of the concrete so that the direction in which trials should be made to determine a fire-proof concrete, if such is possible, might be indicated.

The details given below are chiefly in connection with the former of these divisions, though, as will be seen later, this leads quite naturally to a consideration of the latter.

Concrete essentially consists of fragments of stone held together by a network of mortar. This mortar, in itself, is a finer aggregation, consisting of fine grains of sand, "stuck" together by Portland cement. An examination of concrete shows one peculiarity very strikingly—it is porous. These spaces vary in size from those easily visible to the naked eye, to a mass of fine channels and cavities of microscopic dimensions.

The mode of failure of concrete may be as follows :—

(1) The concrete can be considered to consist of a network of cement holding together stones of various sizes ; if the finer aggregation of mortar is caused to fail the whole mass will be disintegrated quite independently of any effect the coarse aggregate may have.

(2) In such a network structure if all the stones are covered with cement no increase in total volume can take place unless the cement itself expands. When expansion takes place the stresses will be produced in the coating cement and in the aggregate, unless the expansion of the cement is exactly equal to that of the aggregate. These stresses may be sufficient to cause cracking of the cement, or when cooling takes place, may lead to separation between adjacent boundaries.

It should be remembered that as concrete is porous and that a large proportion of the cavities are adjacent to the particles of aggregate, considerable expansion of such particles might take place into the cavities without seriously affecting the surrounding cement. In order to arrive at some idea of the mechanism of failure, the work in the preliminary investigation was simplified by examining the effect of high temperatures on mortars of various descriptions.

The Effect of High Temperatures on Mortars.—It is of great value in attacking this problem to consider first the purely hypothetical case of a spherical sand grain completely surrounded by a cement envelope in close contact with it. This contact might be broken in two ways when the system is exposed to a rise in temperature :

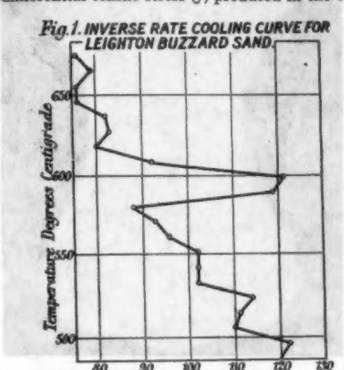
(1) A relative movement between the sand grains and the cement due to differences in their coefficients of expansion might cause either the sand grains, if the coefficient of expansion of sand was less than that of the cement, to leave their cement casing, or, if the coefficient was greater than that of the cement, the sand might expand and burst through the cement.

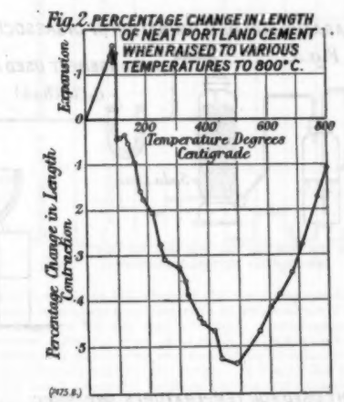
(2) The cement itself may break down under the effect of heat caused by some innate property of the cement, which would take place whether the sand were present or not.

In general then, if (2) were the cause of failure, the breaking down would happen whatever material was mixed with cement to make a mortar (*e.g.*, powdered brick instead of sand), but on the other hand, if (1) were the cause only, it should be possible to form a mortar which, by using a "sand" of the same coefficient of expansion as the cement, would not disintegrate with rise of temperature.

The following work suggests that concrete as at present made in practice, primarily fails through causes found under heading (1), but that though this type of failure can be partially avoided by using rather different materials than usual, then failure occurs by the breaking down of the cement itself as suggested under (2).

Relative Movements of Cement and Sand Grains.—It can be shown that if the cement envelope surrounding the sand grain is considered as a thick walled sphere, the circumferential tensile stress (f) produced in the cement





by a rise in temperature of t deg. C. can be expressed as follows :—

$$f = \frac{(C_1 - C_c)\,t}{\frac{2}{3}\left(\frac{n^3-1}{n^3+2}\right)^{1}/_{k_s} + \frac{1-1/m_c}{E_c}} - \frac{\left(\frac{n^3}{n^3+2}\right)^{1}/_{k_s}}{\frac{2}{3}\left(\frac{n^3-1}{n^3+2}\right)^{1}/_{k_s} + \frac{1-1/m_c}{E_c}}\,p_0$$

Where C_1 = coefficient of expansion of sand (quartz).
C_c = coefficient of expansion of cement.
n = ratio of external radius to internal radius, of cement envelope.
$1/m_c$ = Poissons ratio for cement.
E_c = Young's modulus for cement.
k_s = Bulk modulus of sand (quartz).
p_0 = External radial pressure on cement envelope.

From this expression, which though in itself it does not accurately represent the case usually encountered in practice, various deductions may be made as to the general conditions which effect the failure of cement mortars when exposed to a rise in temperature.

The strength depends upon :—

(1) Coefficient of expansion of sand (quartz or other material) (C_1).
(2) Coefficient of expansion of cement (C_2).
(3) Relative proportions of cement and sand.
(4) The external pressure (p_0) on the spherical envelope.
(5) Bulk modulus of the sand (k_s).
(6) Young's modulus for cement (E_c).
(7) Poisson's ratio for cement ($1/m_c$).

These various factors will now be considered in more detail, and an attempt made to indicate to what extent each is responsible for the ultimate failure.

(1) *Coefficient of Expansion of Sand Grains* (C_1).—The coefficient of expansion of quartz, which is the chief constituent of all sands used in practice, has been fairly accurately determined for ordinary temperatures, and is known to be approximately $13{\cdot}7 \times 10^{-6}$ perpendicular to the axis of the crystal and $7{\cdot}5 \times 10^{-6}$ parallel to the axis.*

At about 575 deg. C. the form of quartz stable at ordinary temperatures (known as the α form) undergoes a change to the β form. This allotropic modification, which is a reversible one, is accompanied by a linear expansion of about 0·4 per cent. This change point can be fairly easily obtained by plotting a cooling curve, and this has been done for Leighton Buzzard sand. One of the curves so obtained is given in Fig. 1.

The only experimental difficulty in obtaining the definite "halt" is due to the comparatively low rate of heat conductivity of such a granular material as quartz sand. The other minor "halts" shown on the curve are due to this effect. Parts of the mass cool down before the rest, but with careful packing of the furnace, this action can be minimised, and though not as easily obtained as a halt due to the solidification, say, of a metal, it is quite well defined.

At about 870 deg. C. this β quartz undergoes another change into the allotropic form of silica, known as tridymite, which, as far as can be ascertained, is accompanied by another expansion. But as will be seen later, these higher temperatures do not matter for our purpose, as in practically all cases of cement-sand mortars the failing point is either below or near 575 deg. C., the temperature at which the quartz changes from the α to the β form with the relatively large expansion of 0·4 per cent.

(2) *Coefficient of Expansion of Cement* (C_c).—When a set cement is heated the effect up to about 93 deg. C. of the coefficient of expansion is quite normal. The specimen extends, and the coefficient of expansion is approximately the same as that of steel. The preliminary experiments give a value of $11{\cdot}6 \times 10^{-6}$ per degree centigrade. It would appear that the fact that this value so closely equals the coefficient of expansion of *concrete* obtained by other investigators, and on which so much stress is laid in considerations of reinforced concrete, is good evidence in support of the deductions given above concerning the structure of concrete. The apparatus used for the determinations was designed by Dr. G. A. Shakespear, and was used by him in 1915 for the measurement of the expansion of metals. It is described in detail in the Appendix.

The whole of the apparatus, except the silica arms which were made in the Physics Department of the University, was made in the Civil Engineering Department. Mr. W. H. Tubbs, M.Sc., gave excellent assistance in making the apparatus, and in carrying out the very laborious observations.

The specimens used were about 4½ in. long, and ½-in. diameter, and some considerable difficulty was experienced in their making. The first supply were all broken when the mould was opened. It is thought that this was due to the contraction on setting, and the fact that the exposed ends probably set first. The difficulty was overcome by making the specimens with as little water as possible, and well ramming. With the cement used, 18 per cent. of water was added in mixing, and the whole mould covered with a wet cloth, and placed in a very moist atmosphere during the time of setting and initial hardening. This produced much stronger specimens, which set at a fairly uniform rate along their length.

It was at first expected that it would take about a week to test one specimen, but experience soon showed that the period involved is more likely to be 20 weeks, as will be seen by the following.

The method of carrying out the experiment was as follows : Trial runs with the furnace had given information as to what current was required to keep it approximately at a certain temperature, then by cutting out resistance until this was obtained, the temperature of the furnace gradually rose until the required degree was reached. At various intervals during this time readings were taken, and this was continued until as nearly steady conditions as possible were obtained. In some cases this entailed keeping the furnace at one temperature for a week or more at a time.

Fig. 2 shows the curve obtained in which the percentage change in length is plotted against temperature. It will be seen that up to about 93 deg. C. the curve is a straight line. At this point a small contraction took place, but after becoming steady, expansion again occurred up to 100 deg. C. At 100 deg. C. a very large contraction started, and this contraction continued until the specimen was *shorter than its original length* before heating.

After 100 deg. C. had been passed it was very difficult to obtain absolute steadiness ; there was a gradual contraction the whole time up to 491 deg. C. The point was assumed to be steady for practical considerations, when after about a couple of days the contraction was only just appreciable.

This gradual contraction with no real steady point agrees quite well with the results obtained from the chemical investigation described later.

After 491 deg. C. is passed expansion commences, and takes place at a rate less than that occurring during the expansion previous to 100 deg. C. The steady conditions are much more easily obtained on this expansion range, and within the accuracy of the apparatus used it is possible to cool down the specimen considerably below the 491 deg. range, and on reheating the same reading will be obtained as before the cooling.

In a latter portion of this paper, the problems of the interpretation of this 491 deg. C. change point, and its

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* Paper read before Section G of the British Association at Hull, September 8, 1922.

† ENGINEERING, vol. xcviii, page 487, "The Effect of Temperature on the Properties of Materials." Proc. Inst. C.E., 1919–20. Proc. Inst. Mech. Engineers, 1922.

* Determination by Benoit. Kaye and Laby "Physical and Chemical Constants."

correlation with the result of chemical investigation is considered more fully.

Though of extreme interest scientifically, the value practically of the exact degree of contraction does not appear to the authors to be very great. If it is once realised that at 100 deg. C. the contraction more than cancels the expansion, and that contraction takes place at higher temperatures up to 491 deg. C. until its value is more than twice the expansion up to 100 deg. C. then very little more accurate data is actually required to analyse the actions taking place in concrete.

(3) *Relative Proportions of Cement and Sand* (n).—It is interesting to note that the actual size of the sand grains does not affect the result as given by the mathematical expression. The point that matters is the relationship between the amount of cement and the amount of sand used, and, as one would expect, the greater the amount of cement, the more resistant the resulting mortar should be. This is actually found to be the case in experimental work. To get some rough idea of what values to take for (n) various sections of cement mortars were polished, and photographs taken. The following approximations have been obtained :—

(1) 1 part cement, 1 part 20/30 L.B. sand (by weight).

$$n = 2 \text{ to } 1 \cdot 5.$$

(2) 1 part cement, 2 parts 20/30 L.B. sand (by weight).

$$n = 1 \cdot 5 \text{ to } 1 \cdot 25.$$

(3) 1 part cement, 3 parts 20/30 L.B. sand (by weight).

$$n = 1 \cdot 25 \text{ to } 1 \cdot 125.$$

(4) *The External Pressure* (p_0) *on the Spherical Envelope.*—It will be noticed that the expression for the tensile stress in the enveloping cement sphere, contains two distinct terms, being connected by a negative sign. The last term involves the external pressure (p_0) on the surface. Then the worst possible case would occur when p_0 is zero as it is not probable that p_0 would reverse in sign and become a radial tensile stress.

This worst case occurs where an isolated sand grain is covered by cement, the outside of which is not attached to any part of a structure, but is exposed to the air only. The point nearest to this condition in a mass of concrete is obviously a sharp external angle and the next, that of a sharp right angle edge, say of a beam or cube. In the centre of a mass of concrete there must be an external pressure of some considerable magnitude. From experimental work and also practical experience it is well known that sharp corners are the first points to fail when a concrete structure is exposed to fire. It cannot be too strongly emphasised how necessary it is in attempting to construct a building of concrete work, to avoid all exposed sharp angles, and the mathematical expression discussed above appears to the writers to indicate why this so important. It is suggested that the use of the name "Form Factor" for this second term in the equation is a suitable one for it is the term which depends upon the form or shape of the specimen.

(5, 6 *and* 7) *The Elastic Constants of Cement and Sand.*—The factors of the equation discussed in the previous four paragraphs are all such as are applicable to either the theoretical case analysed, or to the actual practical conditions. The case now considered is different. For the application of the values of the elastic constants to be valid, the cement envelope must be in intimate contact with the sand grain. We know such is not the case in practice. Concrete is very porous—the sand grains are separated from the surrounding cement by air films in many cases extending nearly all round the grain. Hence some considerable movement of the sand grain can take place before contact is made with the cement and the stressing action analysed above actually comes into play.

The evidence suggests that this property of concrete (porosity) which is usually considered to be so bad from the strength standpoint and also, as will be seen, from the penetration of moisture, is really the one which allows the concrete to withstand greater changes of temperature than would be expected from a rigid application of the equation.

Later it will be seen that theoretically concrete should break down at about 100 deg. C. but that actually it often increases in strength up to about 300 deg. C.

Despite this, the final breaking up of concrete must depend upon the values of these elastic constants though not the values obtained from tests at ordinary temperatures. The only value for the bulk modulus of quartz which the writers have been able to obtain is that given by Hintze ("Handbuck der Mineralogie," page 1314). He states that the coefficient of cubic compression is $25 \cdot 97 \times 10^{-3}$ (gramme millimetre units) or about one-twentieth of water. Expressing this as the bulk modulus in lb. per square inch.

$$k_2 = 54 \cdot 3 \times 10^5 \text{ lb./in.}^2$$

(water is approximately 3×10^5 lb./in.^{2})

An approximate value for Young's modulus for cement is $3 \cdot 4 \times 10^6$ lb./in.^{2} and for Poisson's ratio for cement (obtained from calculation from E and N) one-third.

Numerical Values given by Equation for (f).—If in the equation for (f) the above values are inserted, the results are as shown :—

$n = 2$
$$f = 3 \cdot 55 (C_1 - C_e) t \times 10^6 - 0 \cdot 523 \, p_0 \text{ lb./in.}^2$$
$n = 15$
$$f = 4 \cdot 00 (C_1 - C_e) t \times 10^6 - 0 \cdot 462 \, p_0 \text{ lb./in.}^2$$
$n = 1 \cdot 25.$
$$f = 4 \cdot 41 (C_1 - C_e) t \times 10 - 0 \cdot 418 \, p_0 \text{ lb./in.}^2$$
$n = 1 \cdot 125.$
$$f = 4 \cdot 74 (C_1 - C_e) t \times 10 - 0 \cdot 363 \, p_0 \text{ lb./in.}^2$$

Assuming the initial temperature is 15 deg. C. and the specimens are then raised to 100 deg. C. and that $C_1 = 13 \cdot 7 \times 10^{-6}$ and $C_e = 11 \cdot 6 \times 10^{-6}$. Then—

($n = 2$)	$f = 633 - 0 \cdot 523 \; p_0$ lb./in.^{2}
($n = 1 \cdot 5$)	$f = 713 - 0 \cdot 462$ " "
($n = 1 \cdot 25$)	$f = 786 - 0 \cdot 418$ " "
($n = 1 \cdot 125$)	$f = 845 - 0 \cdot 363$ " "

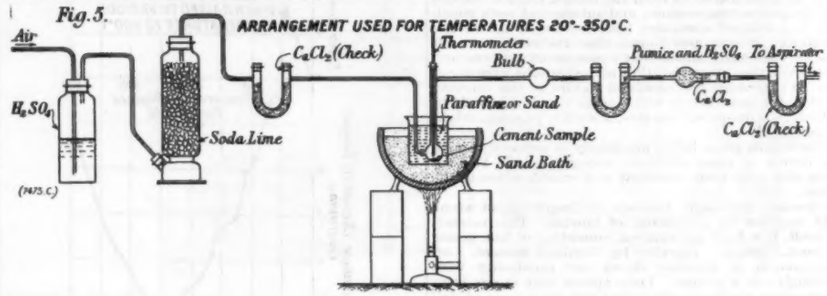
Even if $p_0 = 0$ the tensile stress produced is quite within that which a first-class Portland cement at 28 days' age is able to withstand.

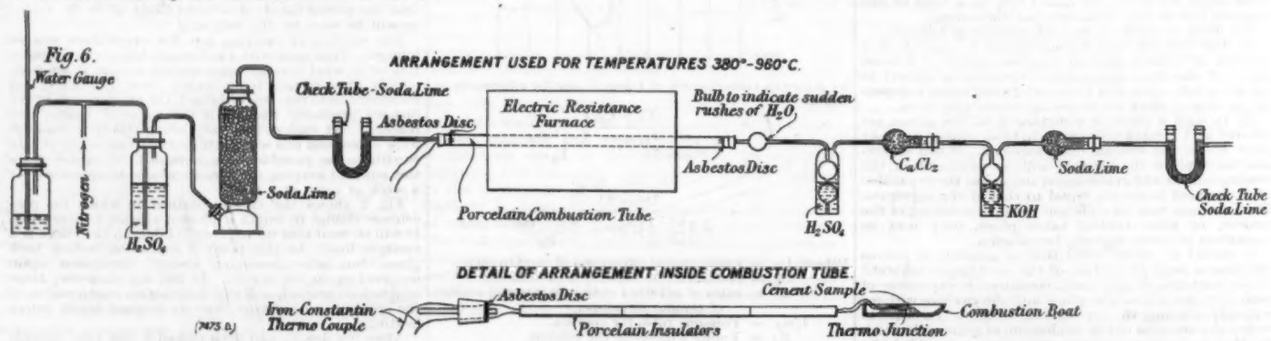
Now, if the mortar is kept at 100 deg. C. until the cement has had time to contract to its original length, then this is equivalent to making $C_e = 0$. The equations then become :—

($n = 2$)	$f = 4130 - 0 \cdot 523 \; p_0$ lb./in.^{2}
($n = 1 \cdot 5$)	$f = 4650 - 0 \cdot 462$ " "
($n = 1 \cdot 25$)	$f = 5120 - 0 \cdot 418$ " "
($n = 1 \cdot 125$)	$f = 5500 - 0 \cdot 363$ " "

FIG. 3.

FIG. 4.





Such stresses, unless p_0 has a very high value, cannot be withstood by a normal Portland cement, and though the writers believe that there is a considerable increase in strength of cement after exposure, in a dry atmosphere, to temperatures about 100 deg. C or slightly over, the increase in strength cannot be supposed to be sufficient to allow the application of stresses of 4,000 lb./in.^{2} to be applied without causing failure. A direct measure of the increase in strength of cement cannot be obtained owing to the contraction cracks which occur when any large mass of geometrical shape such as a tension briquette, is heated.

It is of interest to consider the result of attempting to heat ordinary briquettes of neat Portland cement. The results of such a test are given in Table I.

The examination of the appearance of the briquettes when moved from the furnace (at all the temperatures in the above table) showed the existence of fine hair-line cracks at the lower temperatures (changing to wider cracks at the higher ones) over the whole surface. These cracks are shown in Fig. 3. They have been brought out

for the purpose of photography by means of a thin Canada Balsam varnish.

When tested, the briquettes break along a series of these cracks. This is shown in Figs. 3 and 4, where the actual cracks along which the failure (in Fig. 4) took place have been dotted over in ink in Fig. 3, which was photographed before breaking. As will be shown later, these cracks are due to shrinkage of the cement.

The strength of neat cement briquettes is considerably less after heating above 100 deg. C., and probably if held at that temperature for a long period would have been much weaker still. Further heating reduces the strength as shown, but probably practically the same loss in strength could have been obtained by longer (probably weeks) exposure just above 100 deg. C.

TABLE I.

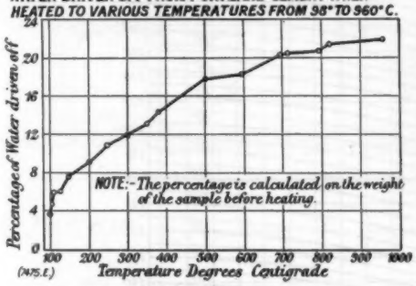
Temperature.	Strength.	Loss.
		per cent.
Unheated	712	—
180 deg. C.	590	17·2
538 deg. C.	316	55·7
620 deg. C.	304	57·5

Since this direct method fails as a means of measuring the strength of neat cement after heating (owing to the formation of cracks) the writers attempted to get some data by the indirect method of hardness measurement, but the experiments are not complete, and no exact values can be given. However, for the present work this is scarcely necessary.

From these *a priori* considerations we would expect that if any cement mortar (and therefore concrete) was raised to and kept at 100 deg. C. for any length of time, then all sharp corners, and probably also the general surface would disintegrate. This is exactly what is found by experiment. Though, as previously hinted, cement mortar briquettes have an increased strength up to about 250 to 300 deg. C., yet all the sharp corners have crumbled and the surface can easily be disturbed with the finger nail.

Before discussing the actual experimental work showing the effect of heat on mortar and concrete, it is helpful to consider what happens when hydrated and hardened Portland cement is heated.

Fig. 7. CURVE SHOWING TOTAL AMOUNT (PER CENT) OF WATER DRIVEN OFF FROM PORTLAND CEMENT WHEN HEATED TO VARIOUS TEMPERATURES FROM 98° TO 960° C.



The Effect of Heat on Hydrated and Hardened Portland Cement.—It has already been shown that the effect of a rise in temperature of neat Portland cement cast in the form of a cylindrical rod is to cause an expansion up to about 93 deg. C., but at 100 deg. C. and up to 491 deg. C. a continuous contraction.

It was considered that useful information might be obtained by an attempt to measure the amount of water driven off from a set cement at various temperatures, and to ascertain if possible what relation, if any, existed between the length changes and the water given off.

The apparatus shown in Figs. 5 and 6 was erected, the water and CO_2 being collected in absorption bulbs (as shown), and weighed. Mr. F. J. Fraser, B.Sc., not only made a very considerable portion of the apparatus, but also gave valuable assistance in carrying out the experiments.

The samples actually used were from a torsion specimen, a small piece being taken and powdered up. About 1·5 grammes were actually used at a time in each apparatus (Figs. 5 and 6). The sample was raised to a certain temperature, and held there for some period. The gain in the absorption bulb was then obtained. The sample was then kept at the same temperature for a further period, and again any change in the absorption bulbs noted. This process was repeated until at any particular temperature there was no appreciable gain in the absorption bulb. The temperature was then raised, and the process repeated and carried up to 960 deg. C. Plotting the results, the curves shown in Figs. 7 and 8 were obtained.

Fig. 7 shows the total percentage of water (calculated on the weight of the sample before heating) driven off up to any temperature between 98 deg. C. and 960 deg. C.

Fig. 8 shows the average percentages of water driven off per degree rise between certain temperatures. In other words, it is the "slope" of the curve given in Fig. 7. This curve shows in a most interesting way various critical periods in the heating of cement.

Up to 98 deg. C. the water driven off may be considered as that contained in the "free" state.

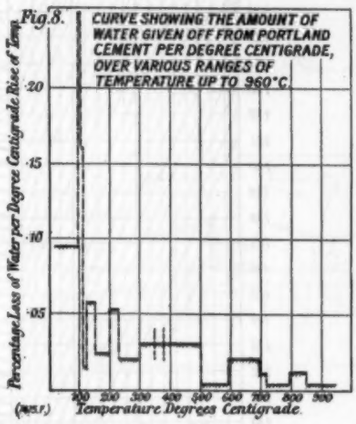
In Table II is given the abstract of experimental data from which the curve in Fig. 8 is plotted. In the second column is given the percentage loss of water during the range of temperature noted in the first column. The third column is obtained by dividing the figure in the second by the temperature range in the first, and hence is a kind of average "rate" of loss of water per degree rise. It is the figures in this column which are plotted against the temperature range in Fig. 8.

TABLE II.

Temperature Range, Deg. C.	Gain in Water Absorption Bulbs, Per Cent.	Percentage Loss in H_2O Deg. C. Rise.	Remarks.
Up to 98	7·56	0·095	Only very approx.
98 to 102	1·00	0·25	Carried out in apparatus shown in Fig. 5.
102 to 110	1·30	0·16	
110 to 120	0·15	0·015	
120 to 150	1·7	0·057	
150 to 200	1·2	0·024	
200 to 230	1·6	0·053	
230 to 250	0·4	0·020	
250 to 300	1·0	0·020	
300 to 350	1·5	0·030	
380 to 500	3·6	0·030	Carried out in apparatus shown in Fig. 6.
500 to 595	0·37	0·0039	
595 to 695	2·03	0·020	
695 to 714	0·20	0·0105	
714 to 796	0·30	0·0035	
796 to 848	0·60	0·0115	
848 to 960	0·40	0·00357	

The curves from Table II are extremely interesting, and give quite useful suggestions. There are two ranges of temperature which have somewhat abnormal characteristics. The first is 200 deg. to 230 deg. As far as it was possible to tell visually (by watching condensation), there was quite a sudden rush of water about 230 deg. C.

Fig. 8. CURVE SHOWING THE AMOUNT OF WATER GIVEN OFF FROM PORTLAND CEMENT PER DEGREE CENTIGRADE, OVER VARIOUS RANGES OF TEMPERATURE UP TO 960° C.



Between 300 deg. and 500 deg. C. there appears to be a rather different type of change. The amount of water driven off per degree rise seemed to be a fairly constant quantity throughout the range. It was in this range that the break occurred between the results obtained in the two sets of apparatus (shown in Figs. 5 and 6). The last range obtained in the lower temperature apparatus was 300 deg. to 350 deg C., and the first one obtained in the higher temperature apparatus was 380 deg. to 500 deg. C. Thus a gap between the results of 30 deg. C. exists. It was rather extraordinary that the calculated amounts of water given off per degree rise in the two cases were the same within the limit of less than ½ per cent. Hence the curve has been assumed continuous, but the actual gap is marked by two short vertical lines at 350 deg. and 380 deg. C. in Fig. 8.

It is not suggested that this curve (Fig. 8) shows exactly the definite change points either in exact position or the relative magnitudes. Obviously the actual temperatures between which measurements were taken must very greatly affect the exact shape of the curve.

It is considered, however, that the following deductions are legitimate, and quite justified by these experiments, and are in harmony with the results of the other experiments.

(1) There are definite ranges during which there are much greater amounts of water given off than at others.

(2) The greatest rate occurs between 98 deg. and 102 deg. C.

(3) As far as the present experiments are concerned, there is no range where a certain amount of water is not driven off by a *rise* in temperature of a few degrees, though in many cases the amount is extremely small.

(4) There appears to be a special range between 300 deg. and 500 deg. C. when water is driven off at a fairly constant rate, and the total amount appears to be about 30 per cent. of the total "combined" water (*i.e.*, water driven off above 98 deg. C.).

(5) After 500 deg. C. is passed, the amount of water given off in the manner described in (3) above is very much less than previous to 300 deg. C.

(6) Though scientifically this work requires repeating with greater care and shorter range of temperature, yet the results already obtained indicate with sufficient accuracy for practical purposes that there are certain ranges during which some definite hydrated Portland cement compounds undergo dissociation from the combined water.

In passing it is, perhaps, worth noting what the type of actions summarised in (1) and (3) above might indicate with regard to the chemical composition of hydrated Portland cement.

The action stated in (1) would suggest the presence of definite hydrates with a definite dissociation temperature, whilst the fact of (2) seems to show that water is also combined in some other way which allows a slow dissociation the whole time, and this might be caused by the presence of a colloidal compound.

There can be little doubt that the contraction obtained in the experiments described previously, as designed to ascertain the value of the coefficient of expansion, is due to this dissociation of water from the hydrated cement.

Both sets of experiments agree in showing that the greatest rate of change occurs at about 100 deg. C. Further, both also show that there is no steady point, and that contraction is taking place the whole time when cement is heated above 100 deg. C. up to about 490 deg. C.

The agreement between the chemical data and the expansion is not quite so clear at temperatures beyond 491 deg. C. The reason for this was not obvious at once, but the following hypothesis which may be ventured is supported by a good deal of experimental evidence. In the microscopic examination of cements the one point which is quite definite, and which has been noted by other workers as well, is that it is not possible to hydrate completely any commercial sample of Portland cement; in fact, in many cases even after every effort has been made, under laboratory conditions, to cause complete hydration, yet about 30 per cent. remains unreached by water.

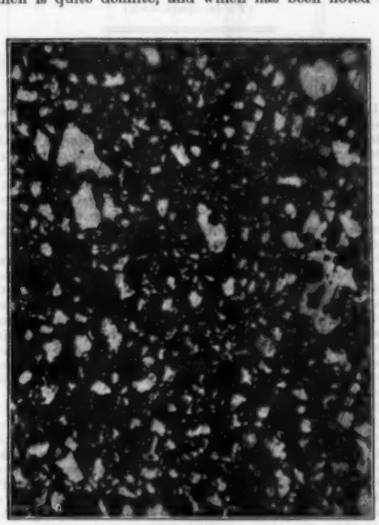


FIG. 9.

Fig. 9 is a photo-micrograph of a sample of set cement. It is obtained by cutting a small specimen from an ordinary standard type of tension briquette, polishing the surface (as in metallography) and etching by polish attack. It is viewed by vertical illumination at a magnification of 100 diameters. The method of etching causes the softer portions (dark in photograph) to be rubbed away and leaves the harder (white in photograph) standing out from the surface.

By further examination of these harder portions, it can be shown that they are unchanged particles of Portland cement clinker, that is, grains which have never been hydrated by the mixing of the cement.

To apply this to the consideration of the effect of heat on neat Portland cement it is only necessary to realise that we are really dealing again with another mortar and not a homogeneous cement.

We have, really, hydrated cement surrounding particles of inert and unchanged clinker, the presence of which is partially due to the coarseness of grinding. It should be realised, however, that these relatively large particles would practically all pass the 180 × 180 standard sieve!

What is likely to occur? When heated there is no doubt that the hydrated portions lose water and contract; this is shown by both the expansion and the chemical tests. On the other hand, is there any reason to assume that the unhydrated and unchanged (since leaving a kiln in which the temperature is 1300 deg. C.–1500 deg. C.) particles contract? It is far more probable that they expand.

It is suggested that the most probable cause of the cracking of hydrated cement is just due to this breaking down of a "mortar." With the comparatively close contact between the hydrated cement and the unhydrated (due to the hydration of a surface layer on these fragments which prevents further penetration of water) the breaking down will commence practically as soon as any contraction takes place, that is, at 100 deg. C. This is exactly what is found by experiment. As the temperature rises more expansion of the unhydrated fragments will take place causing more hydrated cement

to break down. This action will continue until all the unchanged clinker is free to move and expand when the specimen on further heating may expand or contract, depending upon the relative movements of the hydrated and unhydrated portions. This last statement is not quite true as it stands, as probably some of the products of hydration have lost all their water by this time and are helping the expansion rather than the contraction. It is worth suggesting whether this is not due, in the particular case shown in Fig. 2, to the finishing of the dehydration of the calcium hydrate. The curve in Fig. 2 would seem to point to some such action as that outlined above. There is a very marked change point at 491 deg. C. where the movement of the specimen changes quite suddenly from a contraction to an expansion. It would seem likely that at this point (in this particular sample) the hydrated cement is now quite shattered and the expansion now very much exceeds any further contraction taking place during the various ranges up to 491 deg. C.

A further note on the 300 deg. C. — 491 deg. C. range is important. The fact is well known that one of the chief products of the hydration of Portland cement is calcium hydrate ($Ca(OH)_2$). This compound is broken up at about 400 deg. C. into calcium oxide (quick lime) and water. It is suggested that the comparatively great loss between 300 deg. C. and 500 deg. C. is due to the breaking up of this compound. It will be necessary later to discuss the ultimate effect of this in more detail.

(To be continued.)

ECONOMIC STEAM PRODUCTION IN MARINE PRACTICE.*

By A. SPYER, M.Inst.C.E., M.I.Mech.E., M.I.N.A.

IN these days, when the costs of production of every commodity do, and should, receive the closest consideration, attention is directed particularly to this subject. The advocates of the internal-combustion engine rightly call attention to the relatively small percentage of the energy contained in the fuel, which is represented in the work actually done by the steam prime mover, as compared with the percentage of heat units contained in the fuel, utilised in an internal-combustion engine; but as the internal-combustion engine has so far been considered impracticable for large powers as are required in trans-Atlantic vessels for instance, and on large passenger vessels, the steam engine is still a necessity, and independently of this, many engineers favour steam, because of its reliability; and improvements in the utilisation of coal, oil, or other fuel for producing steam are eagerly sought. It is mainly in the direction of superheating and increased pressures that we can look for the possibility of improvement. That there is such a possibility is undoubted.

Fig. 1 is based upon Knoblauch's investigations in regard to the specific heat of superheated steam, first published in 1911, and recently confirmed in 1922—the slight differences then introduced not materially affecting the figures. This figure gives the ratio between the heat contained in 1 lb. of steam from and at 212 deg. F., and that contained in 1 lb. at any desired pressure or superheat temperature, by a simple ready graphic method.

Taking a specific case it is notable that with a feed temperature of 86 deg. F. = 30 deg. C., 1 lb. of steam at 200lb. = 14 kg. gauge pressure, superheated to 707 deg. F. = 375 deg. C., final temperature, contains 1,320 B.Th.U., whereas at a gauge pressure of 350 lb. = 25 kg., superheated to the same final temperature, the quantity of heat contained is only 1,312 B.Th.U. Hence, using steam at a higher steam pressure, which would produce in the engine a larger amount of work, actually less heat is required for its production; in other words the higher pressure is an economical advantage. Moreover, the use of superheated steam, owing to the resulting increased engine efficiency gives also a gain in fuel—which gain is frequently stated at 1 per cent. for each 10 deg. F. of superheat. This, however, is probably on the high side, but it can safely be put at $\frac{7}{10}$ of 1 per cent.

In marine practice in Great Britain, lower temperatures than 707 deg. F. have been in use in the rare cases in which superheat has been installed, but in foreign practice, temperatures of 662 deg. F. have frequently been used without detrimental results, although pressures exceeding 250 lb. are still exceptional for marine use. With turbine machinery, high temperatures and pressures, however, present no difficulty, and the main reason why the higher pressures have been so little utilised in marine practice is the fact that the cylindrical boiler is not adapted for high pressures, neither is it or the reciprocating engine so well adapted for the production or use of high superheats. In land practice, notably in large electrical installations, high pressures and high temperatures have been used to a considerable extent, and may be said to be the standard.

Looking aside from commercial questions, and treating this matter entirely from a scientific point of view, the first thing to consider is an analysis of the heat account. This account is usually split up as follows: (1) The heat contained in the steam produced; (2) the heat contained in waste gases; (3) the heat lost in imperfect combustion and unburnt fuel; (4) the heat lost in radiation and other non-calculable losses.

The heat contained in the waste gases is less easily recuperated in marine practice than in stationary practice. In stationary installations it is common practice, and has been for many years, to effect this by the use of a water economiser. The Howden system for heating the air has also been used for many years, and obtained an excellent reputation, but the use of economisers for heating the feed water has not been very successful in marine work, and the heating of the combustion air does not appear to have been carried very far.

In land practice it has been found that with mechanical stokers in use, the air can be heated, without detriment, to a high degree, and undoubtedly when the mechanical stoker is developed for general use in marine work, further development in heating the air for combustion will follow.

In connection with the question of air heating, there is on record the report of the Parliamentary Boiler Committee of the tests carried out in the R.M.S. Saxonia, where the following results were obtained:—

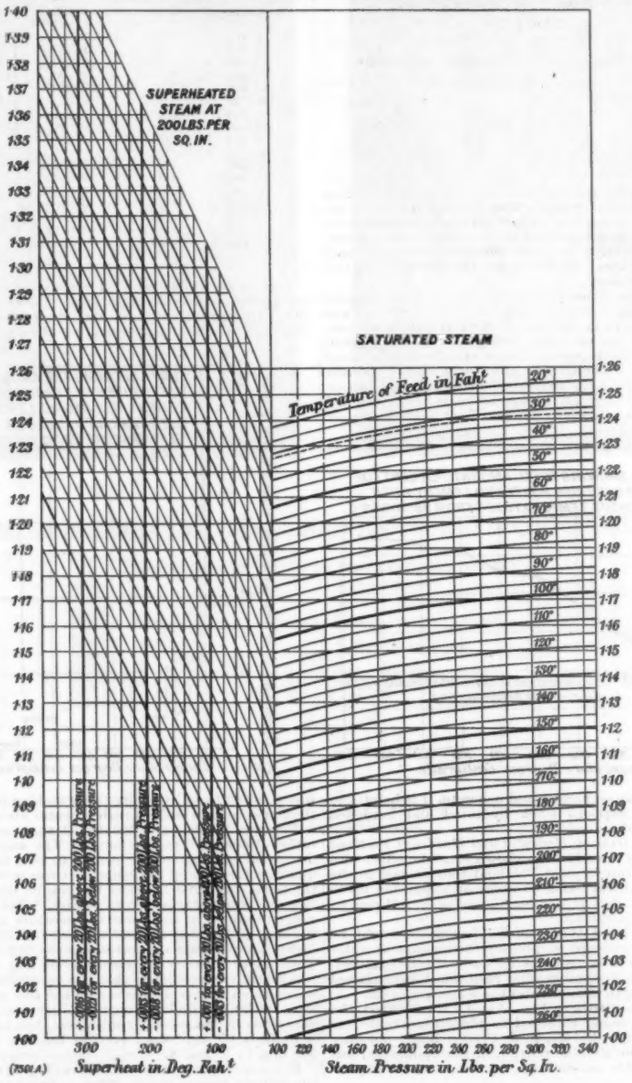
Heat transmission per square foot of heating surface	5,416·0
Pounds of coal per square foot of grate	20·6
	Per Cent.
Total thermal efficiency	82·3
Heat abstracted from waste gas by air heater	3·8

If it is assumed that 3·8 per cent. of the total efficiency is that due to the heat abstracted by the air heater, then the boiler efficiency alone would be 78·5 per cent., a figure which is below that obtained in some of the other types of boilers tried by the committee, and less than what is frequently claimed for cylindrical boilers. This would seem to indicate that only a part of the heat saved by the heater is actually reproduced in the total efficiency.

In marine practice where mechanical stoking is still in its infancy, the use of oil as a fuel is highly advantageous, but it must be recognised that the gain is largely due to the fact that burning oil necessarily carries with it the advantages due to mechanical stoking, and if such system of firing were adapted to solid fuel, then there would not be much difference in the efficiency obtainable. For oil-firing the water-tube boiler, with a combustion chamber which can be shaped to any desired form or capacity and a heat-absorbing surface more suitable for the high furnace temperatures obtaining, is particularly adapted.

It is worthy of note here that with water-tube boilers rates of working corresponding to an average transmission rate of 24,000 B.Th.U. per square foot of heating surface per hour have been attained on test without any damage to the surfaces, and in a single horizontally-inclined tube a transmission rate of 140,000 B.Th.U. at atmospheric pressure has been experimentally obtained.

Fig 1. FACTORS FOR EQUIVALENT EVAPORATION FROM AND AT 212 DEGREES FAHR.


SUPERHEATED STEAM AT 200LBS.PER SQ.IN.
SATURATED STEAM
Temperature of Feed in Fah.t
Superheat in Deg. Fah.t
Steam Pressure in Lbs. per Sq. In.

From the experience in stationary installations, it would seem that there is only a gain of about 1 per cent. in the efficiency obtainable from properly-designed boilers in burning oil as compared with coal mechanically fired, and this is probably due to a diminished loss under item (2) because of the smaller quantity of gas to be dealt with.

The commercial side of the question, however, has, in the case of oil, a very important influence, as with oil there is not only the advantage due to mechanical firing, which on continuous service is of great importance, but there are also no waste products, such as ash and clinker, to be got rid of, and hence the saving of labour is so considerable that oil is advantageously usable at a very largely increased cost per fuel unit, independently of the relative thermal values of the fuel, which is roughly as 3 to 2. In marine work, mechanical firing for solid fuels is still in its infancy, and this is in spite of a considerable increase in efficiency on actual service compared with hand firing.

The great commercial gain with mechanical firing, however, will be found in the fact that this will permit of the mechanical handling both of the fuel and of the waste products, i.e., ash and clinker, and until this side of the matter has been solved, the question of mechanical stoking alone, except for special cases, will move only slowly. Figs. 2 to 7 show a proposition which indicates

* Paper read before Section G of the British Association at Hull, September 11, 1922.

a possible line of consideration of coal and ash handling, but the cost of the alterations and additions for an existing vessel would be very high.

From the technical point of view on actual tests, the difference in boiler efficiency between good hand firing and mechanical firing is not more than about 2 per cent., but under continuous service conditions, this difference would probably be much greater; precisely to what extent it is difficult to say, possibly even 10 per cent. would be shown.

In considering the heat account, the third item is where the trouble really lies. In marine work, the quality of the fuel to be used varies greatly. A ship has to take coal at stations all over the world, and the conditions required for its effective combustion naturally vary, and this makes the provision of such instruments still more important.

The foregoing considerations lead up to the suggestion that for improvements in the economical production of steam for marine work the following propositions must be considered: (A) Higher pressures; (B) superheat; (C) waste heat recuperators, such as air heaters, or economisers; (D) mechanical firing and mechanical draught; (E) mechanical handling of the coal to the furnaces and waste products.

(A) and (B) are possible to-day, because we now have engines of the turbine type and water-tube boilers fully able to deal with high pressures and high superheat.

The auxiliary engines used on board ship are at the present time not generally suitable for high temperatures, and the use of high pressures for some of the auxiliary machinery is also rather open to doubt, but this point can be met by using only slightly superheated steam for the auxiliaries and, if necessary, using steam at a reduced pressure for those it is desired to work at low pressures, and also many of them can be worked electrically, the current being produced by a common generating plant using a high economy steam motor.

The root question in regard to these two items is the use of the water-tube boiler which is necessitated thereby. The prejudice which has hitherto been so strong in this country against water-tube boilers is slowly diminishing, and there are now many marine engineers who have tried them and from experience have realised their advantages. In regard to this, it must be admitted that other nations, notably America, Holland, Spain and Italy, are progressing rapidly and are obtaining in their vessels fitted with water-tube boilers, excellent results, having modified their methods of manipulation to suit.

(C) is a generally-accepted proposition, and as a rule is dealt with in marine practice by fitting air heaters, but the efficiency of the air heater itself is an uncertain factor, and there is no means of ascertaining how much of the heat saved is actually transferred into an increase of overall efficiency—there is necessarily an increased radiation loss and, although the use of hot air should increase the efficiency of combustion, the records of land installations do not show the overall improvement that would be anticipated.

In a few cases in stationary installations, with the object of obtaining the highest possible efficiency, air heaters have been fitted, in addition to feed-water economisers, but the gain obtained appears so far to be hardly commensurate with the capital expenditure involved.

The water economiser has not proved very satisfactory in marine practice, although it is a more effective machine for heat absorption than the air heater, but the causes of the trouble experienced, mainly corrosion, are now known, viz., air and salt water, and if steps be taken to counteract these, there is no reason why water economisers should not be tried again, and with success. One important point in this connection is the design of the feeding arrangements between the condenser and the boiler. The use of the air heater involves in practice the provision of mechanical draught, and the consequent improved control of air supply and draught should be credited with some of the benefit obtained.

(D) The use of the mechanical stoker in conjunction with mechanical draught has already been referred to. The advantages are undoubted. The disadvantages are the extra weight and complication involved, and also the difficulty of finding mechanical stokers suitable for the extensive variety of fuels which have to be dealt with on board ship. This latter difficulty is now overcome, and suitable types of stokers can be obtained, but as already pointed out, whilst the mechanical stoker, under trial conditions, does not show a great improvement over good hand firing, the fact is that skilful hand firing is seldom met with.

To what extent, on actual service, the difference between good hand firing and mechanical firing will obtain, is difficult to say. On test trials, it is not more than about 1 per cent. to 2 per cent., but the mechanical stoker, if properly handled, maintains its efficiency on service, whereas hand firing is apt to drop off very seriously. Quite recently, in Holland, for some vessels serving in the East which would normally have to run with very inferior hand firing, this question is being carefully

Fig.2. CROSS SECTION.

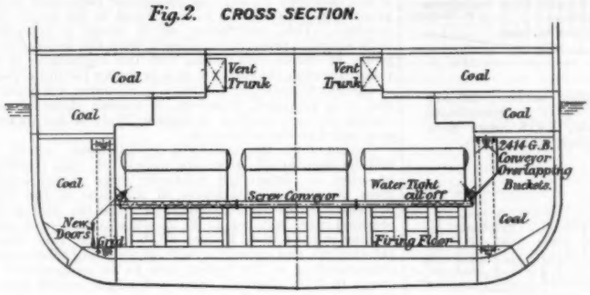


Fig.3. LONGITUDINAL SECTION.

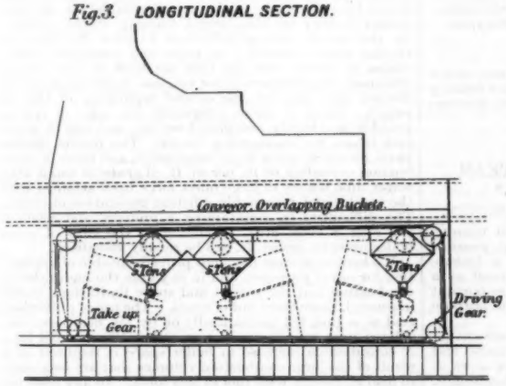


Fig.4. PLAN

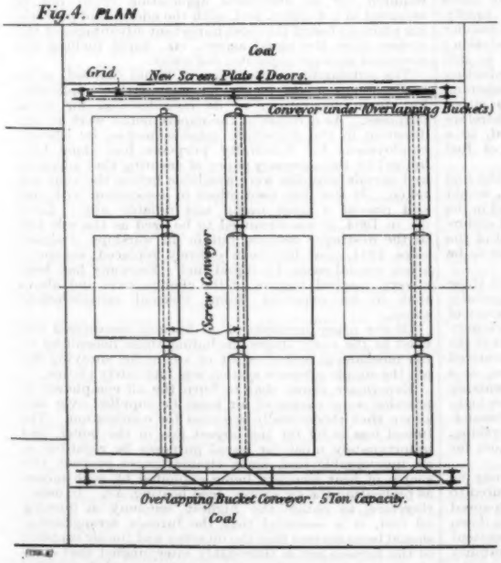


Fig.5.

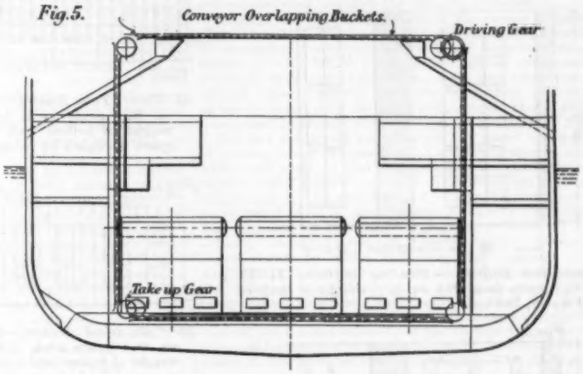


Fig. 6.

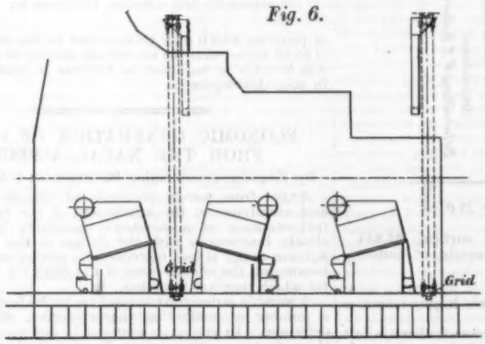
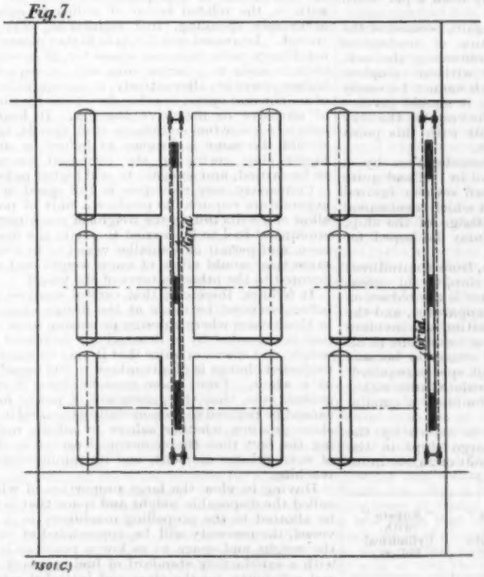


Fig.7.



imperfect combustion—and in regard to this, mechanical firing, associated as it should be with a readily controllable mechanical draught, should give a considerable advantage on continuous service, because the control of the air required for combustion is much easier, and the proportion of unburnt fuel may be less. Unfortunately the instruments required for controlling the boiler performance, such as thermometers, CO_2 recorders, feed-water meters, &c., are, in practice, not usually supplied for marine work, whereas in well-managed stationary installations all these instruments are used, and the conditions carefully noted, and without them correct adjustment of the conditions required to utilise the fuel to the best advantage is not feasible, nor is it practicable to ascertain, in cases of bad performance,

tried out, and the results so far with mechanical stokers seem to be very promising.

In this respect, the water-tube boiler, with its large combustion chamber, which can be shaped to suit, is far better adapted for mechanical stokers than the round furnace of the cylindrical boiler, and therefore it is in the water-tube boiler that this improvement is likely to materialise.

As regards item (4) of the heat account, there is but little room for improvement as in well-designed installations the loss to-day should be only from 2 per cent. to 4 per cent.

(E) The greatest direct commercial gain, because of the saving of labour, lies in the adoption of mechanical methods of feeding the fuel and removing the ash. This side of the question is so far without complete solution. It is an arrangement which cannot be easily adapted to existing installations, as it should involve consideration of the whole design of the vessel in the very first instance, and for ships not built with this point in view, its adoption is very difficult.

The question has been under consideration by a leading shipowner in this country, and in Holland quite recently an important firm of Dutch owners invited tenders in this country for a vessel in which mechanical coal-handling was a feature of the design of the ship, so that progress in this direction may be hoped for soon.

There is still another point, which, from the indirect commercial aspect of steam production, is of great importance in marine practice, and that is the reduction of the weight of the steam-producing apparatus, and the space it occupies. This side of the question also involves the use of the water-tube boiler, as has been done in all the navies of the world, where the situation became long since acute on account of the high speeds required. A saving in weight can always be translated into either greater freight-earning capacity, or building a smaller vessel for the intended service.

An interesting illustration of this is shown by the performance of two similar small cargo ships in the Australian coasting trade where the result of 23,000 miles of running gave the following figures :—

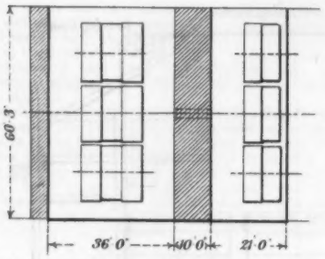
Mean	"Paringa" with Water-Tube Boilers.	"Rupara" with Cylindrical Boilers.
Total displacement	1,700	1,807
Cargo carried	620	517
Indicated horse-power	1,333	1,464
Coal per day .. .. tons	24·07	26·7
Miles per ton	11·40	11·2

Thus the ship with water-tube boilers carried 20 per cent. more cargo, and did the work with 9·8 per cent. less coal.

For high-speed vessels, if they are to be anything like a moderate size, the water-tube boiler is a necessity. The question was recently referred to in a paper read by Sir James Kemnal before the North-East Coast Institution and two typical instances were there given showing the comparison of a typical mail and passenger steamer of 7,500 h.p. and of a liner of 70,000 h.p. Figs. 8 to 11 illustrate this, and the great differences in weight, space and boiler capacity, are very clearly indicated on these diagrams.

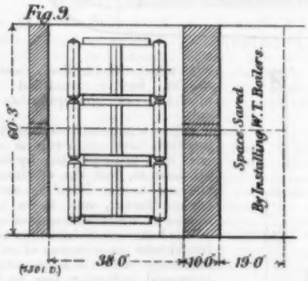
The foregoing is an indication of some possible lines of progress which may be expected in the future, and it is to be hoped that the mercantile marine of this country will be able to maintain as hitherto a leading position in such developments.

Fig. 8. COMPARISON OF BOILER INSTALLATIONS FOR MAIL AND PASSENGER STEAMER OF 7,500 I.H.P.



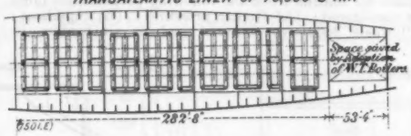
6 *Cylindrical Boilers.* — Heating surface, 21,723 sq. ft.; grate area, 528 sq. ft.; weight of boilers and water, 585 tons.

Fig. 9.



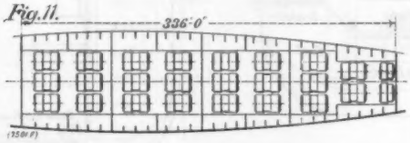
6 *Water Tube Boilers.*—Heating surface, 25,854 sq. ft.; grate area, 650 sq. ft.; weight of boilers and water, 282 tons.

Fig. 10. COMPARISON OF BOILER INSTALLATIONS FOR TRANSATLANTIC LINER OF 70,000 S.H.P.



34 *Water Tube Boilers.*—Heating surface, 221,544 sq. ft.; grate area, 5,474 sq. ft.; approximate weight of boilers and water, 2,615 tons; floor space occupied by boiler rooms, 16,115 sq. ft.

Fig. 11.



25 *Cylindrical Boilers.*—Heating surface, 158,350 sq. ft.; grate area, 4,050 sq. ft.; approximate weight of boilers and water, 4,750 tons; floor space occupied by boiler rooms, 18,235 sq. ft.

ECONOMIC GENERATION OF STEAM FROM THE NAVAL ASPECT.*

By Engineer-Commander R. BEEMAN, C.M.G., R.N.

APART from purely economic advantages in running and maintenance, the attainment of the best possible fuel economy of a warship's machinery is a feature closely interwoven with the design of the vessel as a fighting unit; it has, moreover, on service an important bearing on the effectiveness of the ships for the purpose for which they are intended.

A warship is designed to combine to the best advantage a number of conflicting characteristics, offensive and defensive. In giving prominence to any one or more of these features others must be penalised accordingly. In illustration of this point the effect of speed, and, with it, the related factor of radius of action or more accurately speaking, fuel endurance, may be briefly traced. Increased speed entails higher power and heavier machinery with increased space for its accommodation; thus it leads to a larger ship and consequently to still higher power or, alternatively, to an equivalent reduction of weight and space, in other directions by the weakening of offensive or defensive features. It leads in either case to a lower fuel endurance at all speeds, and therefore should the same endurance as before be desired, to a bigger ship, owing to the increased amount of fuel to be carried, and so again to still higher power.

Conversely, any reduction in full speed or in the fuel expenditure required to produce a unit of power, would allow of a reduction in the weight of machinery and in the amount of fuel to be carried to attain the desired endurance, and permit of a smaller vessel or in a vessel of the same size, would allow of more weight and space to be devoted to the other features of the vessel.

It follows, therefore, that careful analysis of all these influences must be made at the design stage, especially in those cases where a design promising some economy of fuel is attended by a demand for increased machinery weight and space, in order that it may be assured that the projected change is of advantage to the vessel considered as a whole. From these considerations it ensues, as a general rule, that the generation of power in a warship cannot be realised so economically as is usual in other high-class practice whether ashore or afloat, notwithstanding the fact that the economical aspect is, if anything, of even greater moment, and its ramifications more far reaching.

Having in view the large proportion of what may be called the disposable weight and space that is required to be allotted to the propelling machinery in a high-speed vessel, the necessity will be appreciated of cutting down the weight and space to as low a point as is consistent with a satisfactory standard of fuel economy, durability and reliability, for the class and intended service of the vessel under consideration. These standards vary amongst the several classes, and the scantlings of the machinery for a vessel of the torpedo boat destroyer class, for example, in which high speed is an outstanding characteristic and where the weight of machinery and fuel reaches about 50 per cent. of the average sea-going displacement, cannot be apportioned on so generous a scale as in a larger vessel; in particular the larger boiler units and the higher degree of forcing the boilers presents one marked difference in practice.

A considerable portion of a warship's sea-going service is carried out at comparatively low speeds, the higher speeds of which she is capable being only used intermittently as occasion demands. While, therefore, fuel economy is essential at high speeds it has also to be considered seriously for lower speeds, as upon it depends in the main the fuel endurance and, consequently, ability to keep the seas. It is in this feature of requiring a high efficiency at low powers, coupled with the limitations of weight and space, that the naval problem differs mainly from that obtaining elsewhere.

A detailed consideration of all the many influences affecting the question of fuel economy is really necessary if the incidence of any one particular item such as the production of steam, is to be viewed in its proper perspective. This, embracing as it would a somewhat wide range of problems beginning with the generation of power at source, and ending with the application of the power through the medium of a propeller behind a vessel —alone a comprehensive study—is, of course, not possible, and it is proposed, therefore, to confine these remarks mainly to such matters as appear likely to be apposite and useful to the discussion.

Taking first the coal-fired installations, which, as will be mentioned later, are mainly of past interest, in order to obtain the relatively large steam output from the boiler installation in warships it has been necessary to use forced draught to burn the coal at the required rates, viz., up to 30 lb. per square feet of grate surface in cylindrical boilers, 48 lb. in large tube water-tube boilers, and exceeding 60 lb. in the small tube boilers, corresponding in the latter case to an evaporation of about 10·5 lb. of steam, from and at, per square foot of heating surface per hour.

The principal factors by which the most economical results have been obtained are :—By the use of coal found by experience to be most suitable for the particular boiler; by the careful training of the stokers; by the use of stoking indicators to time the firing at regular short intervals; by strict and intelligent supervision to ensure that the fires are kept at the proper thickness and uniformity for efficient combustion at the desired rate, and by the careful regulation of the air supply. Some of these safeguards are only, of course, possible in a highly disciplined service, and one in which cost is not the outstanding factor. The results desired have, however, made them imperative, and rates of combustion exceeding 60 lb. per sq. ft. of grate in small tube water tube boilers in large units have been attained with the regular and reasonably efficient generation of steam. The difficulties in maintaining a uniform and efficient fire over a large area, extending in the case of some boiler units to 100 sq. ft. can be readily visualised.

Mechanical stokers have not proved suitable of application for naval purposes, and in any case the high rates of combustion and the weight and space limitations would in general, place them out of court. The use of pulverised coal as a fuel, fed mechanically or by air, has been considered from time to time as an alternative to solid fuel. A considerable increase in boiler space is required as a result of the large combustion volumes that are necessary to deal efficiently with fuel in this form. In any case the risk of carrying dust in such a finely divided form as is required for its successful application could not be accepted in a warship, and, with the addition of pulverising plant on board the most important advantages of this system from the naval aspect, viz., rapid fuelling and increased stowage capacity, fall away.

The outstanding advantages of liquid fuel led, at an early stage of its increasing commercial application for steam generation, to its consideration for naval purposes. As a result of the experimental work in this direction in the Admiralty establishments, its efficient employment for Admiralty purposes has alone been limited by the necessary policy of ensuring that adequate and certain supplies were available before the step was taken. It was first used afloat in association with coal and proved a most useful and reliable ally. Later on, in 1904, it was arranged to be used as the sole fuel in the destroyer designs, but in all warships designed since 1914, coal has been entirely replaced, except in a few special cases, by liquid fuel. Economy has been a very marked feature of the change, over and above that to be expected from thermal considerations alone.

Of the many methods of oil burning considered and tried in the early stages, including those depending on the mechanical action of air or steam for spraying the oil, the simple pressure system was ultimately chosen.

Experience shows that to burn the oil completely in practice some excess of air must be supplied over and above that theoretically required for combustion. The funnel loss is by far the largest loss in the boiler, and unfortunately must for naval purposes be regarded as an unavoidable loss, since circumstances prevent this source of heat recovery being exploited by such means as preheating the air supply, feed heating, &c. In order, therefore, to obtain the highest economy in burning oil fuel, it is essential that the furnace arrangements should be so devised that the oil spray and the air supplied to the furnace are so thoroughly intermingled that complete combustion takes place in the intended position with the minimum excess air supplied. The realisation of combustion in the intended position is, of course, of considerable moment, as in addition to the non-utilisation of the whole heating circuit, it otherwise may lead to flaming at the funnels, a most undesirable state of affairs from the military aspect.

Excess air beyond that absolutely necessary to achieve combustion entails the further loss represented by the additional power of the forced draught fans supplying the air, which loss may become appreciable when high air pressures are used, as is necessarily the case in highly forced boilers.

On military grounds it is necessary too that the emission of smoke from the funnels shall be avoided so far

* Paper read before Section G of the British Association at Hull, September 11, 1922.

as is possible, and this consideration leads to a rather greater excess of air than would otherwise be required. By reducing the air supply somewhat and permitting some smoke it is found that the boiler efficiency is increased, the loss due to the incomplete combustion being, within limits, less than the loss due to the higher air supply. On the whole, therefore, the entire avoidance of smoke leads to some loss of efficiency. Also, in the desire to ensure a smokeless exhaust the tendency of the operators is to supply more air than is required for that purpose which may lead to a still further loss. Experience shows that between the conditions represented on the one hand by a just visibly shaded exhaust and on the other hand by a white exhaust (the ordinarily accepted indication of incomplete combustion attending an appreciable air excess), there is some scope for the loss of fuel, as fuel.

As is usual, the oil burning arrangements include means for ensuring an intimate admixture of the air with the oil spray before entry into the furnace, the air being supplied by forced draught fans to closed stokeholds as in the case of the coal-fired boilers. The power required to supply the air under pressure is a charge against the power supplied by the boiler, so that it is essential that the mixing arrangements shall not impose an unreasonable resistance in the air circuit. Some of the improvements brought to notice from time to time would probably yield a slightly improved combustion, but the advantage on this account is more than discounted by the additional power required to run the fans. A good deal of attention has been given to the possibilities of improving the efficiency of the air-mixing methods, but the naval problem is complicated by a somewhat wide variation in the properties and characteristics of the fuels which may have to be used and the necessity of a standard type capable of efficiently burning without modification such grades of fuel, sets a limit to the practicable devices.

As is generally known, water-tube boilers have been a feature of naval practice for many years, the saving in weight and space, together with the other military advantages which their use permits, having rendered them imperative to meet the advancing naval needs in respect of high speed, flexibility of operation, &c. The boiler pressure reached in the earlier stages 300 lb. per square inch, but in recent years a somewhat lower pressure has been general, averaging about 250 lb.; the advantages, mainly influenced by maintenance and the auxiliary engine requirements, have been found to rest with this lower pressure.

Under conditions favourable to their respective uses, there does not appear to be any great difference between the maximum efficiencies attainable in cylindrical and water tube boilers. The efficiency falls off, of course, as the rate of forcing of the boilers increases, so that, except when working at relatively low output, the boiler efficiency in the oil fired water tube boiler installations in the naval service is in most cases not higher than about 75 per cent., and, in the case of highly-forced small tube water-tube boilers, less. The loss from this source can only be lessened by providing a more extensive or better baffled heating surface or by a profitable utilisation of the heat in the funnel gases—in other words adding more weight and space. Here, as in other cases, the gain in efficiency due to improved proportions or additional appliances must be balanced against the greater weight and space or other disadvantages. It may be observed in reference to this question that the introduction of higher steam pressures and temperatures so much discussed at present, would be attended by an increased funnel loss in those cases where the surplus heat from this source cannot be effectively employed.

In seeking means of reducing weight and space, the degree to which boilers can be forced with safety has been a matter which has perforce received considerable attention. Rates of combustion averaging 1·25 lb. of oil per square foot of heating surface per hour (corresponding to an evaporation of between 16 lb. and 17 lb. of steam from and at) are general in the small tube boilers of destroyers under full power conditions, and in some special designs of this class of vessel, rates of burning up to 1·4 lb. of oil have been realised. In experimental boilers rates of burning up to 2 lb. per square foot have been attained without any noticeable ill effects. The average consumption for the whole heating surface does not afford any precise indication of the degree of forcing, except perhaps in comparing very similar designs of boiler. The limit to which a boiler can be forced is set by the limit of temperature to which the metal of the heating surface can be raised with safety. Those tubes exposed to the furnace which receive heat from radiant sources as well as from the hot gases passing over them are more highly heat stressed than the tubes remote from the furnace, and in them the greatest transfer of heat takes place. An approximate estimate indicates that about 60 per cent. to 70 per cent. of the total heat transfer may be effected in these tubes.

The temperature which the metal of the tube attains in practice must remain a matter of some doubt, and any estimation a highly approximate one. It depends at source upon the amount of heat transferred and upon the thickness and material of the tube; but in addition it also depends upon the resistance to which the heat transfer from the tube to the medium inside is exposed, and thus upon the proportions of the tube and the nature and speed of flow of the medium inside the tube. If water only were maintained in contact with the tube surface it would perhaps be possible to obtain a better idea of the tube temperature, but this is not the case, and moreover in practice the different tubes and the different parts of the same tube are not exposed to the same conditions. On the furnace side the temperature and velocity of the furnace gases will not be uniform, and on the water side the density of the water and steam mixture will vary according to the particular position considered in the path of the circulation.

It would appear that for the degrees of forcing mentioned the metal temperatures attained are still below those reached in the more highly superheated installations in shore plants where it is believed experience continues to be satisfactory. In any case the extensive experience with boilers forced to the degrees referred to has been satisfactory for the designs to which they are applicable, but it will be appreciated that the care and attention required in operation and maintenance increases with the degree of forcing, and the durability necessarily also falls off.

Reverting to the question of combustion, it may here be mentioned that the combustion of fuel per cubic foot of combustion chamber volume corresponding to the above mentioned rate of 1·25 lb. per square foot of heating surface per hour, is 10·5 lb. At rates of combustion beyond this figure the efficiency of combustion may be prejudiced, although it must also be considered in relation to the adequacy of the cross sectional area of the combustion volume which exercises, as might be expected, an influence on the efficiency.

Superheated steam has been used to a limited extent up to a temperature of 500 deg. F. with advantage, this having been supplied from superheaters generally arranged in the uptakes, affording perhaps a testimony to the relatively low efficiency of the boilers. As a result of the war, necessitating rapid, and to a large extent standard, construction or in any case no very wide departure from existing practice, the Admiralty was not able to respond with the Mercantile Marine in the use of higher temperatures, arising from the satisfactory experience in shore plants. The situation just before the outbreak of war was very favourable to its application by reason of the introduction of the smaller fast running turbines associated with reduction gearing, thereby facilitating the provision of suitable materials—one of the earlier barriers to the application. The advantages are incontestable, and it will be employed for any future naval requirements to a greater extent than hitherto, the superheater being arranged too, at a more suitable position in the furnace gas circuit. The question of economy at lower speeds must also be considered in this application, and the design of the superheater will require to provide for a considerable measure of superheat at low outputs of the boiler, in order that full advantage may be taken of the additional fittings.

The employment of steam at considerably higher pressures and temperatures in order to obtain higher efficiencies continues to receive much attention, but there are many practical problems to be solved and difficulties to be overcome before it can be applied to high powered units such as are fitted in naval machinery. The increased funnel loss in its application has already been mentioned, and it would probably be necessary to modify existing practice and instal means of mitigating this; the gain attending the use of the higher temperature would therefore be somewhat discounted by the additional weight, space and complication of these devices. The more pressing problems calling for solution in this application, however, appear to rest with the metallurgist.

In naval practice the limitations of weight and space react on the economy of the engines no less than the boilers, and the design of turbines and of auxiliaries represents a compromise whereby some degree of economy must be sacrificed in order to save weight and space. It may be noted in passing that the geared turbine now fitted approximates to the fast running turbines fitted on shore for power generation, and the gearing permits of a slower running propeller than was formerly the case with directly connected propellers, thereby leading to improvement in the propulsive efficiency and consequently to the economy in fuel in the attainment of a certain speed.

A considerable provision of auxiliary machinery is made, this being required not only to work the vessel and to provide the amenities for the personnel, but also to fight the vessel. The consumption of the extensive machinery fitted, is responsible for about 15 per cent. of the total fuel consumption at full power. This is a considerable tax on the overall efficiency of the plant, and moreover leads to a greater output being required from the boiler than would be indicated by a consideration of the power required to propel the vessel.

Careful attention is paid to the design of individual auxiliaries to ensure as high a degree of efficiency as is possible, but in many cases their reliability and certainty of action are of paramount importance, and their efficiency must become a secondary consideration. Similarly, on grounds of weight and space, it is seldom possible to take advantage of the most economical type of engine available and the types suitable for application lead to an appreciable handicap in realising an economical installation. These considerations also influence to some extent the efficient generation of steam in so far as the boiler auxiliaries are concerned, and lead to the net efficiency of the boiler being some 3 per cent. less than the gross efficiency indicated by the relation between the heat abstracted and the heat available in the fuel.

It is usual to work the auxiliary engine against a back pressure and to utilise the exhaust steam for feed heating; for supplementing the power of the main turbines (introduced at a suitable part of the circuit); for use as primary steam in the distilling plant and for sundry heating services. Thus the losses attending the use of these expensive steam consumers are palliated in varying degrees.

The use of exhaust steam for feed heating is an important source of economy, and it has been employed to the utmost possible extent on the suction side of the feed pumps. Its advantages in respect of economy (coupled with the important influence it has in assisting to eliminate air and gases from the feed circuit, thereby not only reducing corrosive influences but lessening the load on the air pumps) are likely to lead, at the expense of some further complication, to its use as far as possible on the feed discharge; the balance of advantage on the whole should repay any additional weight required.

While the advantages attending the application for feed heating by the use of steam taken from a suitable position in the turbine steam circuit, and of drying or superheating the turbine steam at intermediate stages by the funnel gases, now finding an increasing use in power plant practice, are fully appreciated, the complexity of the interchange arrangements which are called for on account of the wide range of powers at which warships are manœuvred, renders the devices prohibitive.

Finally, as regards operation of the steam generating plant, it need hardly be said that well considered methods of operating machinery afford many opportunities for economy, and while there is no radical difference in principle from that existing in other first-class practice certain aspects arising from the conditions peculiar to naval practice may be indicated, beside those already mentioned in connection with the combustion of fuel.

For any particular speed below full speed the number of boilers in use is chosen so as to give a rate of output which will yield as nearly as possible the best efficiency, regard being paid to probable requirements as regards higher speed. In war time, of course, all boilers would be required to be in use or available at very short notice. The number of auxiliary engines is reduced to those actually required, and all possible steam ranges are closed down to avoid radiation and leakage losses, which may, in the long and complicated leads throughout the different compartments of a warship, assume some magnitude. Distilled water only is used for boilers, and it is also used to a large extent for domestic purposes in view of the limited capacity of the storage tanks, imposed by considerations of weight and space. Auxiliary exhaust steam at low pressure is largely employed in the evaporators, and by distilling under a vacuum in the evaporator shell the production can be economically effected.

The use of distilled water, while in any case essential for the boilers, carries the important advantage of continued cleanliness of the tube surface and the maintenance of efficient heat transmission. On the fire side another advantage of oil fuel is brought out by the absence of important deposits such as arise with coal. No special arrangements are called for in respect of externally cleaning boilers under way in Admiralty oil-fired boilers, but there are in general sufficient opportunities for cleaning when they are out of use. Attention is given to the air tightness of boiler and funnel casings, leakage in which may lead to important losses of efficiency by the dilution of the furnace gases and the direct loss due to misdirected air supply. This was a very fruitful source of loss in the early days of the water-tube boilers when the design of the extensive casings did not always receive the attention it required, and moreover, when the casings received somewhat rough treatment as a result of inexperience in operation.

Leakage of steam and water in the machinery system is carefully checked and made good, the double loss thus involved being realised, namely, on the one hand loss of heat that could otherwise be put to good purpose, and on the other the fuel it is necessary to expend to make good the loss of water, apart altogether from the inconvenience of leakage.

The designs provide for very carefully proportioned joints and, what is perhaps of even more importance, freedom of movement of all such parts under the influence of expansion.

On the same grounds considerable care is given to the provision of adequate drainage arrangements at all positions where water may accumulate, to ample lagging of the steam ranges and to adequate water area and steam volume together with facilities for a proper circulation in the highly forced boilers. These safeguards all tend to ensure the provision of dry steam to the machinery, on which the realisation by the latter of its intended efficiency so much depends. Attention given to this matter is well repaid in the improved performance of the engines and the freedom from leakage, aside altogether from the running disabilities to which the presence of water with the steam may lead. The use of automatic feed regulators, in any case necessary in view of the relatively small amount of water contained in the water-tube boilers serves to maintain a steady water level and thus contributes to regular and consequently economic generation of steam.

It remains to be added that, when judging cases of what may appear to be extravagance in operation and maintenance, the designer cannot always be acquitted entirely of blame in so far as the arrangements fitted sometimes render efficient maintenance and operation unnecessarily difficult and onerous. The designer's problem in arranging machinery and fittings to the best advantage in the somewhat confined spaces of warships is in any case a difficult one. But it is essential if the arrangements are to continue to realise on service the results obtained at the trial stage, that he should have a close and intimate knowledge of the conditions of service, and should never lose sight of the weaknesses of human nature, keeping also well in view the fact that no single loss of efficiency that can be avoided, however small, can be regarded as unimportant since any one such loss almost always carries other attendant losses in its train.

HYDRO-ELECTRIC POWER IN INDIA.—Sir Ganga Ram, lately Executive Engineer to the Punjab Government who is at present in this country, has placed an order with Vickers, Limited, for water turbines and electrical plant in connection with the development of power on the Bari Doab Canal, in the Punjab. The head which will be utilised is only 6 ft., and the total power obtained will be 1,925 h.p. The energy will be transmitted to various pumping stations, where irrigation water will be raised, enabling larger areas of land to be cultivated.

ECONOMIC STEAM PRODUCTION WITH SPECIAL REFERENCE TO MARINE PRACTICE.

STATEMENT BY THE FUEL RESEARCH BOARD ON HOME-PRODUCED OIL FUEL.*

IN view of the fact that fuel is the fundamental basis upon which economic steam production is established, the initiation of a discussion by the Engineering Section of the British Association on the subject and the invitation to take part in this discussion is welcomed by the Fuel Research Board as an opportunity for bringing up to date certain important economic questions affecting the type of fuel used for the purpose.

In 1892, according to Lloyd's Register, the ss. Bakuin was fitted for burning oil fuel, being in all probability the first oil-burning steamer engaged in continuous sea-service. Since that time engineers have watched with interest the great developments which have taken place in the substitution of oil for coal in ocean-going vessels. During the past fifteen years the gradual replacement of coal by oil has been going on in the Navy, and at the present time almost complete substitution has been effected.

In the mercantile marine developments have been less rapid, owing to the fact that in this service overall economy in working must necessarily be a consideration of greater urgency to those responsible than is the case in the Navy, where the efficiency of the ship as a fighting unit is of immeasurably greater importance than is the cost of working. In this connection, however, it is worthy of note that in the "Report of Lloyd's Register of Shipping for the Year 1920–21," it is pointed out that "vessels to the number of 353, representing 1,867,115 gross tons, or 58 per cent. of the total tonnage of new vessels classed during the year under review, were fitted for burning oil fuel." Again, since July, 1914, the tonnage of vessels burning oil fuel on Lloyd's Register had increased almost tenfold by July, 1921, and involved the replacement by oil of about 20,000,000 tons of coal per annum.

It is difficult to compute the relative costs of running a vessel on coal or oil, owing to the startling fluctuations which have taken place in fuel prices during the past two years. Within that time the price of fuel oil has fallen from about 15*l.* to 3*l.* 10*s.*, while the price of bunker coal has dropped from 4*l.* to something like 22*s.* Were the lower price for oil to be maintained, there can be no doubt as to the possibility of important reductions in the cost of running a ship, while even at the higher figure the economy of labour, convenience of bunkering, saving of bunker space and time, present advantages which outweigh the relative cheapness of coal as a source of the heat units required for propulsion.

The question of home sources of oil supply for the Navy was first exhaustively examined by Lord Fisher's Commission during 1912–13, while emergency inquiries were conducted during the war with the same object. None of these later inquiries added materially to the information which had been collected and verified by the Fisher Commission, whose main arguments are as true to-day as they were in 1912; while, as we have already shown, the urgency of the problem has been greatly intensified. The shortage of oil during the war provides an object-lesson which cannot be safely ignored; and, although the requirements of the Navy have been reduced to pre-war standard, or even below it, the increase in the use of oil in merchant vessels makes the question one of rapidly increasing importance from the national point of view.

The natural source of fuel in this country is of course coal, followed at a considerable distance by peat and oil shale. With regard to peat, the fundamental difficulties of its excavation and drying have hitherto rendered its competition with coal impossible in large scale operations as a source of power and heat. Nor is it likely to become in the near future an economical raw material for the production of fuel oils on a really large scale.

As regards oil shale, the retorting of which has been carried on in Scotland for more than half a century, it is improbable that under present conditions the output of Scottish shale oils could be increased by an amount which would have any appreciable bearing on the problem. The large shale deposits in other parts of Great Britain unfortunately suffer from excess of sulphur, which not only affects the amount of oil distilled, but renders very difficult the production of a marketable oil.

We are forced then to regard coal as the only source from which it would be possible to produce a sufficient quantity of liquid fuel to meet our maritime requirements. Since, as has already been pointed out, no change has taken place in the fundamental basis of the problem since the inquiry of the Fisher Commission in 1912–13, it will be relevant to re-state briefly the main arguments affecting the production of oil from coal, as presented by Mr. George Beilby in a memorandum to that Commission dated October, 1912, in which it was assumed that the yield of fuel oil would amount to 5 per cent. on the coal carbonised. The actual figures now quoted for the yields of oil, coke and gas are those resulting from the long series of experiments recently carried out at H.M. Fuel Research Station.

It is safe to assume that, by practical methods, it is possible to obtain from an average bituminous coal 14 gallons of fuel oil per ton of coal carbonised. Taking the specific gravity as unity, this works out as a little more than 6 per cent. by weight of the raw material used, so that for every 1,000,000 tons of oil produced, 16,000,000 tons of coal must be carbonised, and profitable outlets must be found for about 11,000,000 tons of coke and 56,000,000,000 cub. ft. of rich hydrocarbon gas. From these figures it is obvious that the production of fuel oil from coal by low-temperature carbonisation on any adequate scale involves a revolutionary change in the preparation and use of fuel. Even if the more immediate technical and economic problems of low-temperature carbonisation are successfully solved, the wider economic and financial elements involved in the establishment of a new industry on an enormous scale will have to be faced.

The Fuel Research Board have realised this from the outset of their labours in 1917, and have consistently taken the position that their first duty from the national point of view was to deal with the immediate technical and economic problems; for, until these have been solved on sound lines, it would be futile to face the wider economic and financial questions involved in the establishment of a new industry on an enormous scale. In their recently-issued report on low-temperature carbonisation they have endeavoured to sum up the present position as regards the more immediate technical and economical problems, and to indicate the lines on which it is possible that the solution of these may be arrived at. New and trustworthy data as to the yields and qualities of the products from various types of coal have been obtained, and are now at the disposal of all serious inquirers and workers on the subject.

Should a low-temperature process of carbonisation prove a feasible operation commercially, its first application would probably be to the 35,000,000 tons of coal used for domestic purposes. This would produce about 2,100,000 tons of oil fuel, or considerably more than the peace requirements of the Navy, leaving a quantity which would go far to replenish the tanks of oil-driven steamers when in a home port.

These figures show that the production of fuel oil for the Navy or mercantile marine must largely depend on the possibility of inducing the present consumers of from 10,000,000 tons to 40,000,000 tons of raw coal to change their habits and burn a manufactured form of fuel.

It will be seen on consideration that the present coal-distilling industries cannot be regarded as the source of greatly-increased supplies of fuel oil. The industries in question embrace the illuminating gas and the coke-making trades. The primary object of the former is to manufacture gas for domestic and other uses, while that of the latter is the manufacture of coke for metallurgical and other purposes. The proportions which the products of distillation bear to each other are varied by the characteristic method of distillation which is employed in each case. The illuminating gas manufacturer seeks to increase his output of therms in the form of gas at the expense of the tar and coke, while the maker of metallurgical coke endeavours to obtain the largest amount of hard coke possible. It has indeed only been during recent years that the application of by-product coking has rendered it possible to recover any of the volatile products. It must also be remembered that the uses to which tar and pitch are profitably put for road-making and wood preservation absorb at present the whole output of the gas and coke-making industries, and it is possible that road requirements in this direction may increase in the near future.

The only means by which the maximum quantity of liquid hydrocarbons can be conserved is by the distillation of the coal at a minimum temperature. This principle has long been recognised in the shale oil industry, when at a temperature of 400 deg. to 450 deg. C. a ton of shale yields 10 per cent. to 15 per cent. of oil, and up to 2,000 cub. ft. of rich hydrocarbon gas. In the low-temperature distillation of coal one of the most important products is a coke containing from 8 per cent. to 10 per cent. of volatile matter. This material forms an excellent and absolutely smokeless fuel for domestic purposes, and can if required be burnt under boilers or used as a fuel in suction gas producers. At a temperature of 600 deg. C. the principal products of carbonisation amount to 70 per cent. of coke, 6 per cent. of oil and 9 per cent. of gas.

Since the greater part of the heat units present in the original coal appear in the coke, it is necessary for the commercial success of the process that domestic consumers should recognise its superiority to raw coal in the household grate, and that it should be widely adopted by those who are willing to pay a price slightly in excess of that charged for the household coal which it would replace. The commercial and technical solution of the problem is still unproved, but the Fuel Research Board are not without hope that the converging inquiries of a number of experimenters at the present time may lead to a final success.

The interest of this meeting is naturally concerned more with the question of the suitability of the oil as a fuel for steam raising, or for use in internal-combustion engines, than with the problems presented by the coke and gas. In the recent report of the Fuel Research Board the results are described of an investigation of the oil produced at East Greenwich by the distillation of coal in shallow trays in horizontal retorts. The main results of these inquiries are that from 12 gallons to 18 gallons of oil are obtained per ton of dry coal, the oil having a specific gravity of about 1·05 at 60 deg. F. At this temperature the crude oil is thin and fluid, and remains fluid down to − 5 deg. C. The solidifying point is at about − 10 deg. C.

The crude oil as produced contains a large proportion of emulsified oil and watery liquor which cannot be effectively separated by settling, but can be easily removed by pumping the oil through a filter press. In this way the solid particles which cause emulsification are retained in the filter press, and the filtered liquid is a clear mixture of oil and watery liquor, from which the water can easily be separated by settling at a suitable temperature. The water retained by the oil can thus be reduced to under 1 per cent. After this treatment the material forms an excellent fuel oil with a calorific value of 16,000 B.Th.U. to 16,500 B.Th.U. per pound. Even in connection with the oil, however, some problems remain to be solved. The flash-point of the crude oil is atmospheric, and it is necessary—and from the commercial point of view even desirable—to remove the light fractions. If the flash-point is raised in this way by "topping," to the Admiralty specification of 175 deg. F., a considerable thickening of the residual oil takes place, and at 0 deg. C. it becomes much too viscous. If 8 per cent. of the light oils be removed in this way, the viscosity is such that at 15 deg. C. the oil would meet Admiralty specification, but at 0 deg. C. it would fail. By column steaming, however, it is probable that the desired flash-point may be reached by the removal of a much smaller percentage of light oil, and therefore with a much smaller increase of viscosity.

The question of miscibility with other fuel oils has been shown to have an important bearing on the marine problem. Experiments were carried out with a number of petroleum fuel oils, in order to determine the degree of miscibility, and in only one case—that of Trinidad oil—did the low-temperature product mix in all proportions. In the other cases the range was limited, and when exceeded, resulted in the formation of a gummy, resinous deposit. The following table, giving the results of the miscibility experiments, is taken from the report of the Fuel Research Board for 1920–21, second section:—

Name.	Nature.	Fuel Oil. Sp. Gr. 15 Deg. C.	Proportions Mixed. Tar.	Oil.	Amt.	Separation, Nature of.
Shale ..	Very fluid	0·867	10	90	6	Semi-solid.
			25	75	11	" "
			50	50	14	Black thick fluid.
			70	30	5	" " "
American	Very fluid	0·902	10	90	9	Resinous and gummy.
			50	50	19	" "
			65	35	18	Thick and gummy.
			75	25	4	Black and fluid.
Burmah	Very fluid	0·895	10	90	8	Gummy, resinous.
			25	75	12	Semi-solid.
			50	50	18	Thick, but fluid.
			65	35	24	" " "
			75	24	—	No separation.
Texas ..	Fluid	0·926	10	90	11	Thick and gummy
			25	75	12	" " "
			50	50	20	Thick, fluid. "
			65	35	18	" "
			75	25	—	No separation.
Mexican	Very thick	0·936	10	90	5	Thick, but fluid.
			25	75	10	Fluid.
			50	50	—	No separation.
			65	35	—	" "
Persian	Thick..	0·942	10	90	—	No separation.
			25	75	10	Thick and fluid.
			50	50	20	" " "
			75	25	25	" " "
Trinidad	Very thick	0·968	10	90	—	No separation, when heated during mixing.
			50	50	—	" "
			75	25	—	" "

The questions of flash-point, setting-point and miscibility, though they must not be lost sight of, will only become of importance when the stage is reached at which this new industry can be developed on a scale in which millions of tons of oil must be disposed of.

The foregoing statement is based entirely on the ascertained results of the low-temperature carbonisation of bituminous coal as a self-contained operation; but the work of Dr. Bergius, in Germany, on the hydrogenation of heavy oils and tars, and even on bituminous coal itself, has opened up new possibilities in the production of liquid fuels from coal. It is claimed that in this way the yields of petrol, Diesel oil and fuel oil, from coal, can be enormously increased. If these claims can be substantiated the consequences will be of far-reaching importance. The Fuel Research Board have therefore been in close touch with Dr. Bergius and his colleagues for the past year, and hope ere long to be in a position to study the process and its possibilities at first hand.

CHARCOAL AND COKES FOR GAS ABSORPTION.—Since the various kinds of charcoal and coke used for the preparation of "active" carbon, i.e., a carbon suitable for the absorption of gases and fumes, vary much in their efficiency, and the most efficient are expensive, the Institut für Kohlenforschung, at Mülheim on the Ruhr, has been investigating the suitability of various carbonaceous materials for this purpose (*Brennstoff Chemie*, August 15). The materials, coal, lignite, briquettes, peat, saw-dust, wood, leaves of trees and ferns, were, so far as necessary, carbonised under the same conditions in electric furnaces in the presence of steam and cooled in an atmosphere of nitrogen. The subsequent absorption tests were made with benzene vapours. The benzene stripping of coal gas by means of washing, though greatly improved, is not perfect, and in fact nearly a third of the benzene is left in the gas. In the absorption tests of the various active carbons the so-called zinc-chloride carbon of the Elberfeld Farbenfabriken came out by far best, but the material is expensive; zinc-chloride is, in some way not divulged, used in the preparation of this material.

*Read by C. H. Lander, D.Sc., M.I.Mech.E., A.M.Inst.C.E., before Section G of the British Association at the Hull meeting, on September 11, 1922.

ECONOMIC STEAM PRODUCTION WITH SPECIAL REFERENCE TO MARINE PRACTICE.*

By Engineer-Commander FRASER SHAW, R.N.

THERE are two distinct questions embodied in economic steam raising, namely, what method is commercially economic, and what method is economical of fuel. Unfortunately, as everybody knows, while fuel was cheap in this country the interests of these two economies were very widely divergent, if not actually opposed. Even now with dear fuel, although these interests do pull better together, there is a very distinct point beyond which it is not commercially economical to take the steps which are necessary in order to burn fuel in an economic manner.

When any question arises between the two it is, in these days, naturally the commercial economy which wins the argument. If we wish our stores of fuel to be utilised in a truly economic manner from the fuel point of view, then it is first of all up to us to prove that the process is commercially economic (in the broadest sense). Otherwise we can hardly expect that the people who are financing the plant will fall in with our wishes.

You are all doubtless aware of the campaign which certain eminent engineers have been waging for years against the deplorably wasteful conditions under which fuel is burnt in by far the majority of land boiler plants throughout the country. These gentlemen are able to point out that the average efficiency of the Lancashire boilers and tank boilers of that class throughout the country is only 54·7 per cent. compared with a maximum efficiency of 59·5 per cent., and a minimum of 51·8 per cent. With water tube boilers the efficiency is better, being on the average 60·3 per cent. with a maximum of 65·8 per cent. and minimum 59·9 per cent.

I have taken the liberty of quoting figures given by Mr. Brownlie in his various publications. While fuel was cheap these apostles of efficiency, although supported by all informed engineering societies and Government Departments, had a very uphill battle and made remarkably little headway, entirely because the commercial man had not been convinced that commercial economy was involved.

With the increased cost of fuel of all sorts the commercial man is awaking to the fact that it is a business proposition to expend more money on the effort to use fuel economically, and he is prepared to accept the advice of experts so that his efforts may be directed on scientific lines. Hence we find that at the present moment there is quite a brisk trade in CO_2 recorders, draught gauges, pyrometers, thermometers, water meters, steam meters and other scientific instruments which, when rightly used, give us information as to what is taking place between the furnace mouth and the chimney.

In addition to these instruments, whose chief object is to ensure correct conditions of combustion, we have certain fittings external to the boiler which also abstract heat from the flue gases. Steam superheaters have been in vogue for quite a long time, chiefly because the steam engines called for them, not I am afraid, because they are a means of taking more heat out of the flue gases; and now to these are added economisers in the form of either feed-water heaters or air preheaters. An average overall efficiency of boiler, superheater and economiser of 81 per cent. (59·5 per cent., 6·2 per cent. and 15·3 per cent. respectively) is obtained in practice from a good installation of Lancashire boilers, while corresponding figures for water-tube boilers are 83·1 per cent. (65·8 per cent., 9·7 per cent. and 7·6 per cent.).

As may be expected, to obtain these figures first-class stoking is required, and it is probable that part of the increased efficiency of the water-tube boiler over the Lancashire, is due to the fact that the former is fired mechanically and is not dependent on even the best hand stoking.

Considering the boiler alone, it would appear that the increase in the loss in the case of an inefficient plant with Lancashire boilers, compared with an efficient plant of the same type, amounts to about 8 per cent. About 6 per cent. of this loss may be ascribed to incorrect combustion conditions (*i.e.*, inefficient stoking). If the loss due to air-leaks through enclosed settings is greater than 2 per cent. then it is probable that the overall loss would be increased correspondingly to 18 per cent.

When I have spoken above of inefficient stoking I am perhaps a little unfair to the stoker himself, for part of the blame certainly attaches to the engineer, who, as he is not making suitable tests of the composition and temperature of the flue gases, draught, &c., is unaware that inefficient combustion and heat transference, due to one cause or another, is taking place in his boilers. But fundamentally the loss is directly attributable to the fact that, while the constant skill and attention of a sufficiency of thoroughly able men are required to keep a boiler working at its maximum efficiency, such men and numbers cost money, and the commercial man has not been convinced that it will pay him to spend more money in this direction so as to save more than its quota on fuel.

It is small wonder then that the commercial man is very ready to listen when a system of firing is put forward which is practically entirely mechanical and is so simple in manipulation that it is almost difficult not to burn the fuel efficiently. Such a happy state of affairs exists in any of the good systems using liquid fuel, pulverised coal or gas. In each of these cases it is a matter of very little practice for an ordinarily intelligent stoker to be able to tell by eye when correct combustion is proceeding, by observing the condition of the flame and the colour of the waste gases.

The efficiencies commonly obtained in boilers used on land with furnaces suitably designed for these special fuels amount to :—

	Per Cent.
Liquid fuel	84
Pulverised fuel	80
(90 per cent. has been reached)	
Gas fuel	85

I do not propose to go into details of these systems further, because, unfortunately, the two latter systems, pulverised coal and gas, have not yet reached the stage of adaptation for marine purposes, while liquid fuel will, I understand, be dealt with extensively by other speakers.

Pulverised coal seems to be put out of court for the present, for marine purposes, by the very large extra weight of conveyors, driers, crushers, ducts, &c., though I understand that satisfactory results have been obtained when using this form of fuel in the furnaces of an ordinary return tube marine boiler.

Although gas is similarly of the almost foolproof variety of fuels (so far as combustion is concerned), it is doubtful whether it would pay to make it in producers and to burn it under boilers on board ship, when the efficiency and weight of the producers is taken into consideration. This weight of course is additional to that of the ordinary boiler installation, though the weight of a gas-fired boiler would be very considerably less than that of a coal-fired boiler of similar capacity.

At sea, then, we find in use the coal-fired single and double-ended return tube tank boiler, and various forms of water-tube boilers. By far the majority of the latter are in use in the Navy, and I shall leave them to be dealt with by other speakers.

When we compare the tank boiler as used on board ship with the varied types of tank boiler used on shore, we see at once that the marine boilers, although at a disadvantage in being cramped into a comparatively small space and habitually forced to a greater extent than land boilers (the relative rates of consumption of fuel being :—Land boiler, 27 lb. per square foot of grate area. Marine boiler, 45 lb. per square foot of grate area), still have one advantage in being entirely self-contained, and not liable to losses owing to leaky brick settings. Any avoidable loss which does occur then must be due to the inefficient working of the human element in the plant as a whole.

In the single ended return tube marine boilers working under really good sea-going conditions, an efficiency of 61 per cent. has been obtained and may be expected. A figure given for a poor average result from such a boiler is 55 per cent. This gives us a loss of 6 per cent. of the fuel used to lay to the charge of the human element.

When one looks round and realises the conditions under which the firemen exist in by far the majority of ships in the mercantile marine, one can only be surprised that the men who can support such an existence have intelligence enough to get even 55 per cent. efficiency out of their boilers. The marvel is that these men can do it, and have shown over and over again in many desperate straits in peace time, and still more often in the late war what splendid stuff there is in them. This does not alter the fact that the conditions in very many cases are deplorable, just how deplorable is very well told in an article by Admiral Boyle Somerville, which was published in *Blackwood's Magazine* in February, 1920, entitled "The Ninth Cruiser Squadron," also at greater length in Fleet-Surgeon Horne's book entitled "Merchant Seamen, their Diseases and Welfare Needs."

These firemen at sea are paid at the rate of 8*l.* 10*s.* per month, food being found, while the stokers on shore receive 4*l.* 15*s.* per week for 8 hours per day, including Sundays. The pre-war rates worked out as follows :—At sea, 4*l.* 10*s.* to 5*l.* per month all found; on shore, 3*l.* to 3*l.* 9*s.* for 8 hours per day, seven days per week.

You will notice that there has been a distinct relative improvement. You will forgive me if I quote a few lines from the article mentioned which gives Admiral Somerville's summing up of the situation :—

"More lies in this illumination of a dark corner—a great deal more than the plainly obvious need for a change in such conditions. For what is the result? Only the most miserable and the most ignorant of men, unemployables of all sorts and sizes, and from all causes, will enlist into a life so deeply far below the common lot of men. It seems, indeed, to be supposed by the recruiters that no special training is necessary for the duties of a fireman—that 'anybody' will do. Anything so truly insane can scarcely be conceived. Stoking is a skilled profession, and if properly instructed men were employed in the merchant service the saving in coal would run into thousands of tons every year, and even in every month."

While allowing a certain discount for the bias which must exist in any naval man's mind with regard to the cleanliness and general conditions suitable for seamen and stokers, which he has always seen produced by unlimited labour backed by a paternal Government, it must be incontestable that the first necessity, if a reasonable economy in the consumption of fuel is desired, must be in a vast improvement in the working conditions in the mercantile marine in order that a better type of fireman may be attracted to follow the sea by good conditions, in addition to all the attraction which is embodied in the phrase "See the world, and get paid for doing it."

The accommodation of seamen and their conditions of service form a very difficult and many-sided question. Several firms have attempted improvement in conditions. Some, particularly in those ships burning liquid fuel, have met with satisfactory response from the men, but others have been discouraged into apathy by the same sort of misuse, abuse and destruction of fittings which is met with in so many cases when improved housing is introduced into the slums of our large cities. Here again we have to face the question "Is it economic from a commercial point of view to provide this better accommodation, to pay this higher wage and so obtain the services of a type of man who should be able to burn our fuel efficiently?"

The British merchant ship has to compete with all the world, including Chinese and Dagos of all sorts, and must herself earn all that is spent upon her. In this competition it is, unfortunately, a fact that certain owners who have tried to improve matters so far as accommodation is concerned have found that they have improved their ships out of existence so far as economic running is concerned. When once a ship is built alterations of crew space, &c., almost always involve structural alterations, which however slight are bound to be expensive. It certainly would appear on the other hand that a considerable betterment in conditions might be effected in all new ships, on the lines carried out in the "standard ships" built during the war. I am afraid that at the moment the earnings of most coal-fired merchant ships warrant but little expenditure on improvements in accommodation, &c., for the crew.

How different is the case with liquid fuel! With this system in use not only are the conditions in the boiler room incomparably less irksome, but the boiler room complement is so reduced in numbers that better accommodation and higher wages can be well afforded.

Apart from the fireman who actually stokes the boilers, I have already mentioned the use of CO_2 recorders and pyrometers, &c., in land practice. These are almost unknown at sea. In fact, I think I am right in saying that it is only within the last few years that CO_2 recorders suitable for use at sea have been brought out. They have now been introduced into several first-class high-speed ships, but these form only a minute percentage of our coal-burning mercantile fleet. As all those conversant with these instruments will agree, no one must imagine that the simple installation of the instrument will be of any advantage unless it is properly looked after and its readings correctly interpreted. I am not at all sure that the really "foolproof" indestructible instrument has yet arrived; it is something of this type which is essential to success at sea, as many manufacturers of more delicate mechanism and electrical appliances have proved to their cost.

I feel also that I must give a word of warning about the interpretation of the readings registered on a CO_2 recorder. My warning is, naturally, not addressed to experts, but to the ordinary run of sea-going and land engineers who, I feel, are like myself apt to think that if the CO_2 recorder shows anything in the region of 12 per cent. or 13 per cent., we may be satisfied that we are steaming economically. This, of course, is not necessarily the case. A minute's inquiry will show that a record of 13 per cent. of CO_2, and no knowledge of the composition the remaining gas does not carry us very far. If 6 per cent. of the waste gases be oxygen, well and good; combustion is perfect, we are using 40 per cent. excess air, and are discharging 13 per cent. of the heat of the fuel in the waste gases (quite a reasonable figure). On the other hand, if 2 per cent. only be oxygen, very far from well; we find that combustion is not perfect; although we are using 10 per cent. excess air, as much as 5·5 per cent. of the waste gas will be CO, and we are discharging 28 per cent. of the heat of the fuel up the funnel.

It is extremely unlikely that the presence of CO (due to inefficient air passing into the furnace over the fire) would be detected by any means other than a chemical test. It is, therefore, essential to know the quantity of either the oxygen or CO, in addition to the CO_2, if we are to be certain on what lines our combustion is proceeding.

This point was brought home to me by the student engineers, Mr. H. H. Hurley and Mr. W. J. Sparkes, who are working with me at the Fuel Research Station, in the course of a certain boiler trial carried out on the Lancashire boiler which is installed at the station for trial purposes. The student engineers have since worked out a method representing graphically the proportions of CO_2, CO and oxygen in flue gases, loss of heat in flue gases, and excess air supplied, in such a way that if any two of these items are known the remainder can at once be read off. I feel sure that many engineers would find such a set of graphs of great use. So far I have not been able to hear of any other representations giving similar information.

For varying conditions, such as obtain in the boilers in use at sea, I am inclined to the opinion that an apparatus which records any one constituent of the waste gases is of little use by itself, and to be useful must be supplemented by a further apparatus which records another of the three constituents CO_2, CO and O_2.

Another point in which marine practice in general falls behind land practice is in the use of economisers. Superheaters on the other hand are used to quite a considerable extent, chiefly, as it appears to me, at the demand of the steam engines.

Economisers, as before mentioned, may take the form of feed-water heaters or air preheaters. The former are much more generally used in land installations than the latter. There is seldom enough heat in the flue gases for both. At sea, where the steam engines are always surface condensing, and where there is as a rule a larger proportion of auxiliary engines than on land the exhaust steam is such an efficient means of heating up the feed water, and is so readily applicable to that work, that it is not economical to use the waste gases of the boiler for this purpose. The heat in the waste gases may be made use of much more efficiently in pre-heating the air which is being supplied to furnaces. By a drop of about 200 deg. F. in the temperature of the waste gases a similar rise of about 200 deg. F. may be expected in the air delivered to the furnaces.

At the very least this extra heat passing through the boiler will act instead of a definite quantity of fuel (about 6 per cent.), while it has been definitely established

* Paper read before Section G. of the British Association at the Hull meeting, on September 11, 1922.

that the increase in furnace temperature of 200 deg. F. will give a greater furnace efficiency than before. This principle of high furnace temperature is carried to its limit in the various systems for burning liquid fuel, pulverised coal and gas, where the furnace is raised to as high a temperature as the furnace brickwork and setting will stand.

Another means to economy appertaining more to marine than land practice is the use of retarders in the return tubes of the marine boilers. A retarder formed of a twisted strip of thin plate of width equal to the internal diameter of the tube naturally obstructs the draught, and in general is only suitable for use in connection with some form of forced draught. For this reason apparently retarders are not in general use in land practice. Forced draught is usually available at sea and economy amounting to about 5 per cent. of the fuel used is gained by the use of these simple instruments. On the other hand, they do add considerably to the difficulty and labour of sweeping tubes. The most general form of steam superheater fitted to marine boilers, a steam tube led into the fire tube from the smoke-box end partakes of the nature of a retarder and to some extent has the same effect.

One more item which appeals to me as peculiarly suitable for use in tank boilers in marine service, is some form of circulator which is effective while raising steam. On land tank boilers are habitually under steam for months on end, but in the sea service almost every time a ship enters a port some of the boilers, if not the majority, are allowed to die right out. There are on the market certain perfectly satisfactory forms of automatic circulators which commence to work almost as soon as the fires are lit, and very soon remove all the cold dead water from the bottom of the boiler to the great direct benefit of the boiler itself, and also at a considerable saving in fuel owing to the reduction in time necessary for raising steam without ill effects to the boiler. When actually steaming it is doubtful whether these circulators do much good, but they certainly can do no harm.

I have added these few items at the end of my paper as a reminder that all the simple means to the exercise of economy are not in use in every ship although, probably, all and more than I have mentioned are in use in many ships, and I feel that the remarks of Sir George Beilby, the Director of Fuel Research in the report of the Fuel Research Board for the years 1918, 1919, apply to marine practice just as much as to land practice, namely :—

"It follows from these considerations, that in any practical programme for fuel economy the first place ought to be assigned to the putting in order without loss of time, by the consumers themselves, of a system of control which will ensure that a stop shall be put to gross waste, and that the existing appliances and known methods are worked to the best advantage."

THE STRENGTH OF RAILWAY BRIDGES.*

By J. S. WILSON, A.C.G.I., A.M.Inst.C.E.

THE various aspects of the problem of the strength of railway bridges can, I think, be brought to your notice in the shortest time by referring to the case of the Torksey Bridge. It will enable me to indicate how there can be differences of opinion between representatives of a Government department and the railway bridge engineer, and the effect of those differences ; it will also enable me to refer to a few interesting points relating to the design of the early wrought-iron bridges of which there are so many splendid examples in this country.

When an extension of the Manchester, Sheffield and Lincolnshire Railway, between Retford and Lincoln, was being inspected in 1849 preparatory to its opening to the public, Torksey Bridge across the Trent was tested by the representative of the railway commissioners. The bridge gives two river openings of 130 ft. clear, and consists of a platform wide enough to carry a double line of way, supported by wrought-iron plate girders, the Fairbairn tubular type.

In the test two locomotives with their tenders were arranged at the centre of each line on one of the spans. Their total weight of 148 tons gave a deflection of 1¼ in. This was considered excessive, exception was taken to some parts of the workmanship, and the inspector did not feel sufficient confidence in the bridge to recommend the Commissioners to authorise its use. On this the Commissioners deferred the opening of the line for a month. The engineer responsible for the work was John Fowler, later Sir John Fowler, who, in partnership with the late Sir Benjamin Baker, was responsible for the Forth Bridge. Having received some of my training in Sir John Fowler's office, many years after of course, I can easily imagine the effect on him of such an occurrence.

What appeared to be very arbitrary action on the part of the Railway Commissioners could not but cause great consternation among all bridge engineers of the day. The girders had been designed in accordance with proportions used by Fairbairn, and Fowler was quite satisfied with the bridge. He suggested to the Commissioners that some mistake had been made and at his own request more severe tests were made. The inspector's report on these tests stated that they confirmed his calculated deflection of 1·42 in. under the higher test load, and that he still considered it inadvisable to use the bridge. The opening of the line was therefore postponed for another month. These difficulties over the Torksey Bridge occurred just after the Royal Commission appointed to inquire into the application of iron to railway structures had made certain recommendations. The principle one reads as follows : "That, as it has been shown that to resist the effects of reiterated flexure iron should scarcely be allowed to suffer a deflection equal to one-third of its ultimate deflection, and since the deflection produced by a given load is increased by the effects of percussion, it is advisable that the greatest load in railway bridges should in no case exceed one-sixth of the weight which would break the beam when laid on at rest in the centre."

The Commission made a large number of experiments. Practically all were on cast-iron, and it was uncertain whether the recommendations applied to wrought-iron girders. The provision in the recommendation for the increase by the "effects of percussion" over and above that due to reiterated flexure, is of interest at the present moment. It was based on several series of experiments in which rolling loads were made to pass over cast-iron test beams placed as rails in an experimental track. In order that the beams should deflect enough to be measured easily they had to be very slender, and although 9 ft. long the depth of some was as little as 1½ in. It was found that by increasing the speed of the trolley the deflection of these beams increased very much, and that a load which a test beam could carry easily if stationary, just as easily broke the beam if rolled over it rapidly. The results were alarming at the time, and I think some of the alarm still subsists. In the very careful analysis of those tests made by Professor Willis which was attached to the Commissioners' report, allowances were made for the extreme slenderness of the test beams and for the gross disproportion between the weights of the beams in comparision with the rolling loads. Those allowances reduced the effects that might be expected in real structures to an almost negligible amount, a result which was verified by tests made on two cast-iron girder bridges. On one of them, a 48-ft. span, an engine while stationary produced a deflection of one-fifth of an inch, and at 50 miles an hour the increase in deflection was only one-seventh part of that. Whether the effect of velocity increases the load on a girder has been doubted from the very beginning, and Bidder, the celebrated engineer, wrote in 1850 that "he believed it to be a mere ghost raised by mathematicians to frighten engineers as to the strength of the structure, and he thought the engineers were bound, as standing between the mathematicians and the public, to apply to the deductions the principles of commonsense."

A point I am anxious to call your attention to is that the engineers responsible for the early bridges based their designs and estimates of strength on the breaking strength. For instance, Hodgkinson evolved proportions for cast-iron girders and experimentally got a coefficient in a simple formula which would give the weight which would break any properly-designed girder,* and a quarter of that weight was considered a perfectly safe load for building purposes.

For wrought-iron girders, Fairbairn used a simple formula with a coefficient derived from the numerous tests he made on models of tubular girders, and to return to the Torksey Bridge, I give you Fairbairn's calculations relating to the strength of those girders :—

His formula was $W = \frac{a\,d\,c}{l}$ where a was the area of the bottom flange which had to be $\frac{1}{6}$ of the area of the tubular top boom, d was the depth in inches, l the length in inches, and c a coefficient which he found to be equal to 80.

SECTIONAL AREAS AT CENTRE.

Top Boom.

Longitudinal plates (2), 2 ft. 8⅛ in. by ⅞ in. ... ... =	24·47
Vertical plates (3), 1 ft. 1½ in. by $\frac{5}{16}$ in. =	12·42
Angle irons (9), 4½ in. by $\frac{5}{16}$ in. ... =	13·35
	50·24
Area calculated by Commissioners' representative ... ... =	51·72
Mean	50·98

Bottom Boom.

Longitudinal plates (2), 2 ft. 9 in. by ⅞ in. ... ... =	41·25
Centre strip (1), 1 ft. by ⅞ in. ... ... =	9·00
Packing strip (2), 3½ in. by ⅞ in. ... =	4·68
	54·93

Effective area of bottom boom = 50·98 by ⅞ in. = 46·76 sq. in.

$$\text{Breaking Weight} = \frac{46{\cdot}76 \times 120 \times 80}{130 \times 12} = 287{\cdot}7 \text{ tons.}$$

287·7 × 4 = 1,152 tons uniformly distributed breaking weight over two girders.

Deadweight of span = 177 tons.

"Resisting force to heaviest rolling load" = 1,152 − 177 = 975 tons.

Heaviest rolling load agreed by Commissioners = 195 tons.

$$\text{Ratio } \frac{975}{195} = 5.$$

The margin of strength was therefore 5 : 1, but if the deadweight had not been deducted it would have been nearly 6 : 1. These calculations assume the spans to be independent of one another, and the Commissioners' inspector assumed that too, but the girders were really continuous over the centre piers, and that made a large addition to the margin of strength. After calculations and arguments by several eminent engineers had been put to the Commissioners' inspector the reply he made was that the bridge would not be in a condition for use "until it shall have been so strengthened that a load of about 400 tons distributed equally over the platforms of one span, shall not produce a greater pressure upon the top plate of the girders than 5 tons per square inch." Basing the safe strength of a girder on stress rather than on its breaking strength must have been an innovation, for stresses in those days appear to have been a minor consideration, just as we at the present day would think the ultimate breaking load of a bridge girder. According to statements made at the time, fixing an arbitrary stress like this thoroughly roused many eminent engineers of the day.

Fowler protested against 5 tons per square inch being considered the greatest stress permissible with safety and mentioned that experiment had shown that 8 tons was perfectly safe, and that no good authority had recommended less. However, the opening of the railway was postponed for another month.

Fowler eventually convinced the Commissioners by further experiments that the girders did act as continuous girders, and maintained that under those circumstances the stresses were actually below 5 tons per square inch. He also offered to reduce slightly the weight of ballast on the flooring. The Commissioners' inspector finally agreed to pass the bridge as safe with the reduced ballasting, but in doing this he pointed out in his report that with the common live load of two-thirds of a ton per foot run on a single line the stress would still be up to 5·22 tons per square inch in top and bottom booms over the centre pier, and that that live load on both lines would produce stresses of 6·06 tons per square inch, even without allowing for the rivet holes. The railway was eventually opened after a delay of from three to four months, and it will be easily realised that the holding up of a railway for so long because the stresses exceeded 5 tons per square inch would be a pretty strong inducement to engineers to keep stresses below that limit in future bridges.

You may like to know the subsequent history of that interesting bridge. It is still there. For forty-six years, from 1850 to 1896, it remained as originally erected, carrying all traffic satisfactorily. In 1896, in order to assist the cross-girders which must have been the weakest part of the structure, a longitudinal girder was added between the two lines of way, so that during the seventy-two years since its erection, in spite of the increase in axle loads from year to year, whatever the stresses may have been the old girders have withstood them.

I have given this brief account of the Torksey Bridge only because many aspects of the railway bridge problem are illustrated. I do not want to suggest that the Government authorities intended to do anything but act in the best interests of the public. Few wrought-iron bridges were in existence at the time, and the authorities acted cautiously.

The comparison between the old and the modern methods of computing the safe load that can be put on a riveted girder is worth considering. In the old method the ultimate breaking load that the completed girder can carry must be determined by experiment or inferred from experiment, before the desired safe fraction of it can be calculated, whereas in the modern method some arbitrary safe stress may be used. It is obvious that the ultimate strength of a girder would depend to a large degree on the exact disposition of the parts and on their connections as Fairbairn proved in his model experiments, and in any attempt to arrive at the ultimate strength by calculation would necessitate a very careful consideration of the successive effects of the gradual increase in the strains. It would be impossible to neglect the web plate of a girder, for instance, or the vertical edges of the angles, or the effect of end connections or continuity of girders, and if these would affect the ultimate strength they would equally affect the safe load so long as the connections were good.

In their attitude toward riveted structures of iron and steel I think engineers may be divided into pessimists and optimists. In my experience the greatest optimists have been those most closely associated with the maintenance or actual construction. As to the effects of over-loading, I think the optimists with their good inspection must be right. I do not think a girder in daily use is like the proverbial camel, and that there is one single last straw that is going to bring about sudden disaster. I think there would be many last straws, spread over a considerable period and during that time the girder would show signs of distress just as would any real camel.

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* Introduction to the discussion before Section G of the British Association, at Hull, on September 7, 1922.

* $\frac{a \times d \times c}{l} = W$

where a = area of bottom flange (square inches) = one-sixth of area of top flange.
d = depth of girder (inches).
c = a constant = 25.
l = length (inches).
W = breaking strength (tons single load at centre).

RUBBER PAINT.—In 1920 the Rubber Growers' Association offered a number of prizes with a view to encouraging the more extended use of rubber. Among the awards was one of 500*l.*, divided among five competitors, for the use of rubber in paints. We have received lately from Mr. G. Assante, whose address is Corso Garibaldi, No. 234, Naples, Italy, particulars of an interesting test to which a rubber paint patented by him has been subjected. A plate of steel was painted on one side with Mr. Assante's rubber paint, and on the other with a well-known brand of English paint used for ship's hulls, and left for a year under water in the harbour at Naples attached to the propeller of an old ship. At the end of the twelve months the ordinary paint was found to have preserved the steel fairly well, but as a preventive of fouling had not proved nearly so satisfactory as the rubber paint. The latter is said also to have kept the surface quite free from rust, so that when the paint was removed the metal was quite bright. The ordinary paint had been applied in two coats, but the rubber paint in one only, so that Mr. Assante's rubber paint would appear to be economical, if sold at a reasonable price, as well as effective.